RF/EMM/WP-01-003.UN
Revision 0

KAISER•HILL
COMPANY

RMRS Rocky Mountain Remediation Services, L.L.C.
... protecting the environment

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

FINAL

SOURCE EVALUATION REPORT FOR RFCA POINT OF EVALUATION GS10

WATER YEARS 2000-2001

August 2001

SW-A-004457

RF/EMM/WP-01-003.UN; Revision 0

Final Source Evaluation Report for Point of Evaluation GS10 Water Years 2000-2001

August 2001

U.S. Department of Energy

Rocky Flats Environmental Technology Site

Golden, Colorado

2

TABLE OF CONTENTS

3

FIGURES

TABLES

6

1 EXECUTIVE SUMMARY

Rocky Flats Environmental Technology Site personnel have completed the most recent source evaluation related to the possible cause(s) of elevated 30-day moving average values for plutonium and americium[1] at the Rocky Flats Cleanup Agreement (RFCA) Point of Evaluation (POE) monitoring location GS10 (Figure 1-1). First reported on June 29, 2000, the reportable values may be summarized as:

- Reportable values were observed at the POE monitoring location on S. Walnut Creek upstream of the B-Series Ponds (referred to as GS10) for the periods April 15-June 22, 2000, July 10-August 14, 2000, August 27-September 19, 2000, and April 11, 2001.

When reportable values are measured at a POE, RFCA requires the Department of Energy (DOE) to notify the RFCA parties and submit a plan for "source evaluation". RFCA requires a source evaluation for POEs when specific constituents are measured above Action Levels; this Report fulfills that requirement.[2]

This Source Evaluation Report includes data collection and analysis activities as detailed in the *Sampling and Analysis Plan for Automated Synoptic Surface-Water and Sediment Sampling for the GS10 Source Investigation* (RMRS, 2000). This report also builds on the results of the previously completed GS10 Source Evaluation Reports (RMRS, 1997b, 1997c, 1997d, 1998, and 1999). For this report Site personnel have extensively evaluated environmental data, collected additional sediment and water samples for analysis, and assessed Site activities. Site personnel conclude that the likely sources of the reportable 30-day moving average values at GS10 are the following:

1. Diffuse actinide contamination associated with soils and sediments from past Site operations released to the environment through events and conditions over past years. This actinide contamination is transported with suspended solids in surface-water runoff during precipitation events.
2. Actinide contamination enriched in americium that has been incorporated into the stream sediments in South Walnut Creek from past Site operations through events and conditions over past years. This actinide contamination is transported through sediment resuspension by surface-water runoff during precipitation events.

Based on this source evaluation and the available information, no localized source(s) of contamination that warrant targeted remediation have been identified. This Report contains no specific recommendations for source control due to the reportable values measured at GS10, other than scheduled remedial actions and closure activities for the Site.[3]

---

[1] In this report, 'plutonium' or 'Pu' refers to Pu-239,-240 and 'americium' or 'Am' refers to Am-241.

[2] The RFCA requires reporting "when contaminant concentrations in Segment 5 exceed the Table 1 action levels" and that "source evaluation will be required". Further, RFCA states "if mitigating action is appropriate, the specific actions will be determined on a case-by-case basis, but must be designed such that surface water will meet applicable standards at the POCs" (Points of Compliance).

[3] Future Site Closure and environmental remediation activities already scheduled for the Site should positively influence water-quality at GS10.

1

The Site's current proposed course of action includes continued environmental monitoring and progress on the Actinide Migration Evaluation (AME) project. Effective best-management practices, such as the use of the existing terminal ponds in batch or flow-through mode to clarify stormwater of potentially contaminated sediment and particulate matter, should be continued. Specifically, the Site proposes the following actions as the path forward:

- Continued monitoring and ongoing data interpretation to provide a better understanding of actinide transport directly related to the operation of the Site automated surface-water monitoring network.
- Continued progress on the AME as a longer-term technical study to provide understanding of actinide migration that may eventually provide insights into the cause(s) and possible prevention of reportable radionuclide water-quality measurements.
- Continued use of the existing detention ponds to clarify stormwater of potentially-contaminated sediment and particulate matter as an effective best-management practice.
- Continued reporting through AME reports, Quarterly RFCA Reports, Quarterly State Exchange Meetings, and informal technical briefs.

Figure 1-1. Location Map for RFCA POE GS10.

See attached map.

9

2 BACKGROUND

This Source Evaluation Report is provided in accordance with the *Final Rocky Flats Cleanup Agreement* (RFCA) (CDPHE et al., 1996) (Attachment 5, §2.4(B)) under "Action Determinations". The RFCA requires reporting "when contaminant concentrations in Segment 5 exceed the Table 1 action levels" and that "source evaluation will be required". Further, RFCA states "if mitigating action is appropriate, the specific actions will be determined on a case-by-case basis, but must be designed such that surface water will meet applicable standards at the POCs" (Points of Compliance).

Specifically, this source evaluation addresses the June 29, 2000 Rocky Flats Environmental Technology Site (Site) notification of reportable 30-day moving average values for plutonium and americium water-quality results at the POE monitoring location GS10, located above Pond B-1 in S. Walnut Creek. Reportable values for Pu were measured for the periods April 29 through June 22, 2000, July 16 through August 14, 2000, and August 27 through September 19, 2000. Reportable values for Am were measured for the periods April 15 through June 22, 2000, July 10 through August 14, 2000, and April 11, 2001. This Source Evaluation Report specifically includes data collection and analysis activities as detailed in the *Sampling and Analysis Plan for Automated Synoptic Surface-Water and Sediment Sampling for the GS10 Source Investigation* (RMRS, 2000).

This Report for Walnut Creek gaging station GS10 covers data received through May 4, 2001. The following are included in this Report:

- Summary of current applicable Actinide Migration Evaluation findings;
- Evaluation of ongoing automated surface-water monitoring including automated synoptic sampling within the GS10 drainage;
- Estimated actinide loads within the GS10 drainage area;
- Evaluation of Pu/Am ratios within the GS10 drainage area;
- Evaluation of water-quality correlations;
- Evaluation of existing soil/sediment data as well as recent sediment sampling within the GS10 drainage; and,
- Assessment of Decontamination and Decommissioning (D&D), Environmental Restoration, and Site Closure projects.

2.1 Hydrology

North and South Walnut Creek Flow Controls

All Industrial Area (IA; the developed area within the Inner Security Fence) surface-water runoff that flows into North or South Walnut Creek is collected by a system of stormwater detention ponds. The ponds serve three main purposes for surface-water management: (1) storm water detention and settling of sediments, (2) water storage for sampling prior to release, and (3) emergency spill control in those instances where a spill cannot be adequately managed without use of the ponds.

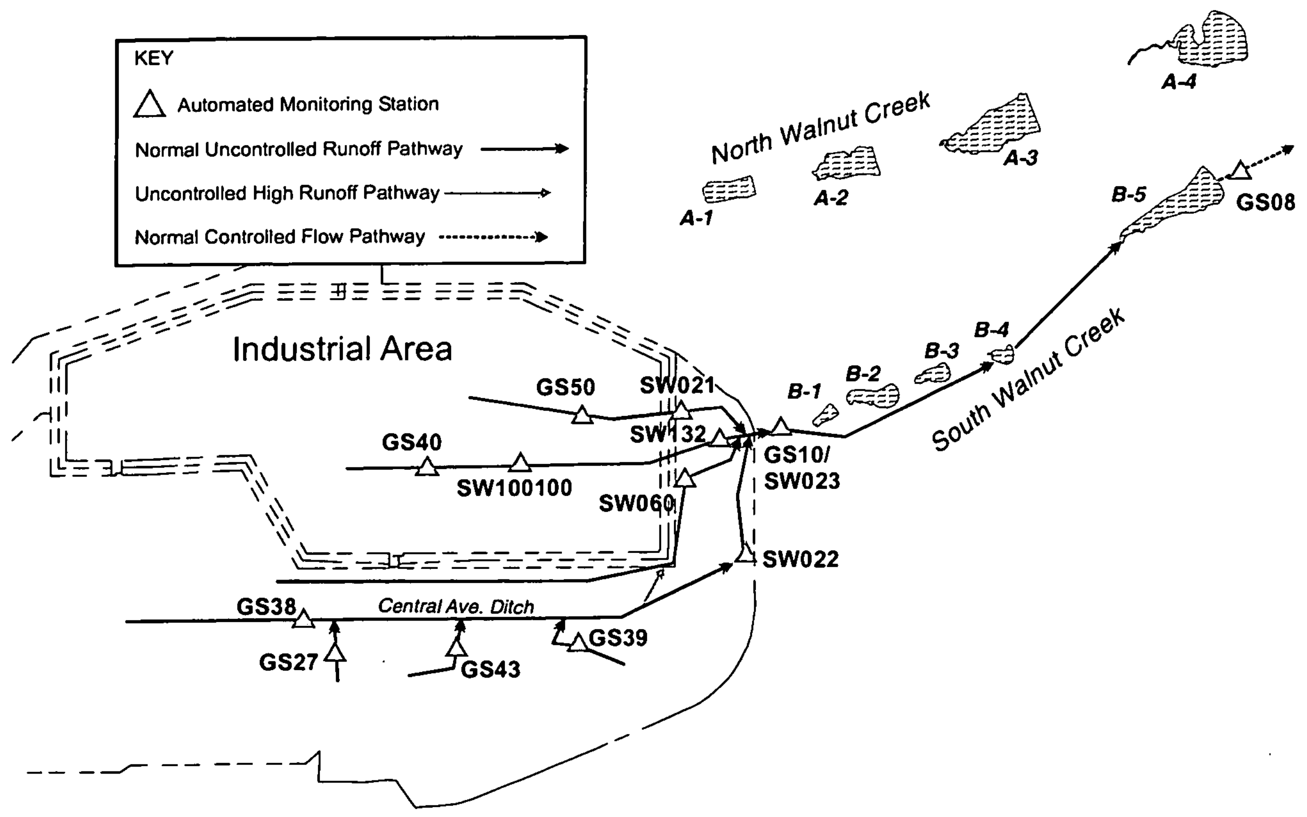


Figure 2-1. Hydrologic Routing Diagram for POE GS10 (WY2000-2001).

GS10 is the POE for IA surface-water flows to South Walnut Creek. Surface water in S. Walnut Cr. is routed through the B-Series ponds (Figure 2-1). Steps in the water collection and transfer process are briefly outlined as follows:

- Runoff from the south-central IA flows through the Central Avenue Ditch past monitoring location SW022, and then past GS10 (during high runoff periods, some water in the Central Avenue Ditch overflows to a large corrugated metal pipe and flows directly to GS10; shown by the blue line in Figure 2-1);
- Runoff from the central IA flows directly to GS10;
- Runoff from GS10 then flows downstream through conveyance structures, through Pond B-4, and then to Pond B-5 where it is detained; and
- Water detained in Pond B-5 is discharged periodically in batches to Walnut Creek.

As indicated above, all of the IA runoff that flows into South Walnut Creek is ultimately routed to Pond B-5, detained, and sampled prior to being released to lower Walnut Creek. There is no source of IA runoff to S. Walnut Cr. that can enter Lower Walnut Creek without first passing through the pond system for subsequent batch discharge from Pond B-5.[4]

---

[4] A gate structure exists immediately below SW022 that can be configured to allow Central Ave. Ditch water to flow directly to Pond B-5. However, this gate is normally configured to direct flows to GS10.

12

2.2 GS10 Monitoring Results

As specified in the *Integrated Monitoring Plan* (IMP; Kaiser-Hill / DOE RFFO, 2000), Site personnel evaluate 30-day moving average values[5] for selected radionuclides at POE surface-water monitoring location GS10. Recent evaluations of water-quality measurements at POE GS10 show reportable values for Pu and Am requiring notification and source evaluation under the RFCA Action Level Framework. Results for recent 30-day moving average values using available data at GS10 are summarized below in Table 2-1 and are shown on Figure 2-2.

Table 2-1. Recent Water-Quality Information from GS10.

Location	Parameter	Date(s) of 30-Day Average Requiring Reporting	Date(s) of Maximum 30-Day Average	Maximum 30-Day Average (pCi/l)	Volume-Weighted Average for Water Year[6] 2000 (pCi/l)
GS10	Pu-239,240	4/29 - 6/22/00; 7/16 – 8/14/00; and 8/27 – 9/19/00	6/7 – 6/12/00	1.3	0.19
GS10	Am-241	4/15 - 6/22/00; 7/10 – 8/14/00; and 4/11/01	6/7 – 6/11/00	4.7	0.4

The analytical results for the composite samples collected around the period of reportable values have been verified. A review of historical GS10 monitoring data shows that these results are somewhat higher than usual. Additionally, the Am levels measured at GS10 are higher than typically measured at other gaging stations given the measured plutonium levels.[7] Storm-event[8] samples collected at GS10 from WY92 through WY96 (under pre-

---

[5] The 30-day moving average activity (pCi/l) for a particular day is calculated as a volume-weighted average for a 'window' of time containing the previous 30-days which had flow. Each day is assigned the activity of the composite sample that was filling at the end of that day (specifically 23:59). Each day has a corresponding measured discharge volume in liters, which is multiplied by the assigned activity to obtain daily load in pCi. The equation for the 30-day 'window' can be written as follows:

$$\frac{\sum_{day=1}^{day=-30}[picocuries]}{\sum_{day=1}^{day=-30}[liters]} = 30 - day\ Average_{day=1}[pCi/l]$$

When a negative result is returned from the lab due to blank correction, a value of zero pCi/l is used in the calculations. Therefore, there are 365 30-day moving average values for a location that flows all year (366 in a leap year). For days where no activity is available, either due to failed laboratory analysis or non-sufficient quantity for analysis (NSQ), no 30-day average is reported.

[6] A Water Year is defined as the period from October 1 through September 30. The term water year is abbreviated as WY; e.g. Water Year 2000 is WY2000 or WY00.

[7] Pu levels in the environment at RFETS usually are greater than Am levels. Ratios of activities of co-existing radionuclides may provide valuable insight into the origin and age of radionuclide materials -- in effect a radionuclide "signature". Pu/Am ratios (Am-241 being a daughter of Pu-241 and found in man-made plutonium) at RFETS typically show values greater than

RFCA protocols[9]) had an arithmetic average Pu activity of 0.25 pCi/l with a maximum of 1.4 pCi/l. For the same period, the arithmetic average Am activity was 0.22 pCi/l with a maximum of 1.0 pCi/l. Additionally, during the period of continuous flow-paced monitoring under RFCA, there were multiple occurrences of reportable 30-day average values for both analytes (Figure 2-2). The reportable measurements generally occur during periods of increased stormwater runoff in the spring and summer months (Figure 2-3). Individual composite-sample results for GS10 are listed in Table 2-2 and plotted in Figure 2-4 for the period of interest.

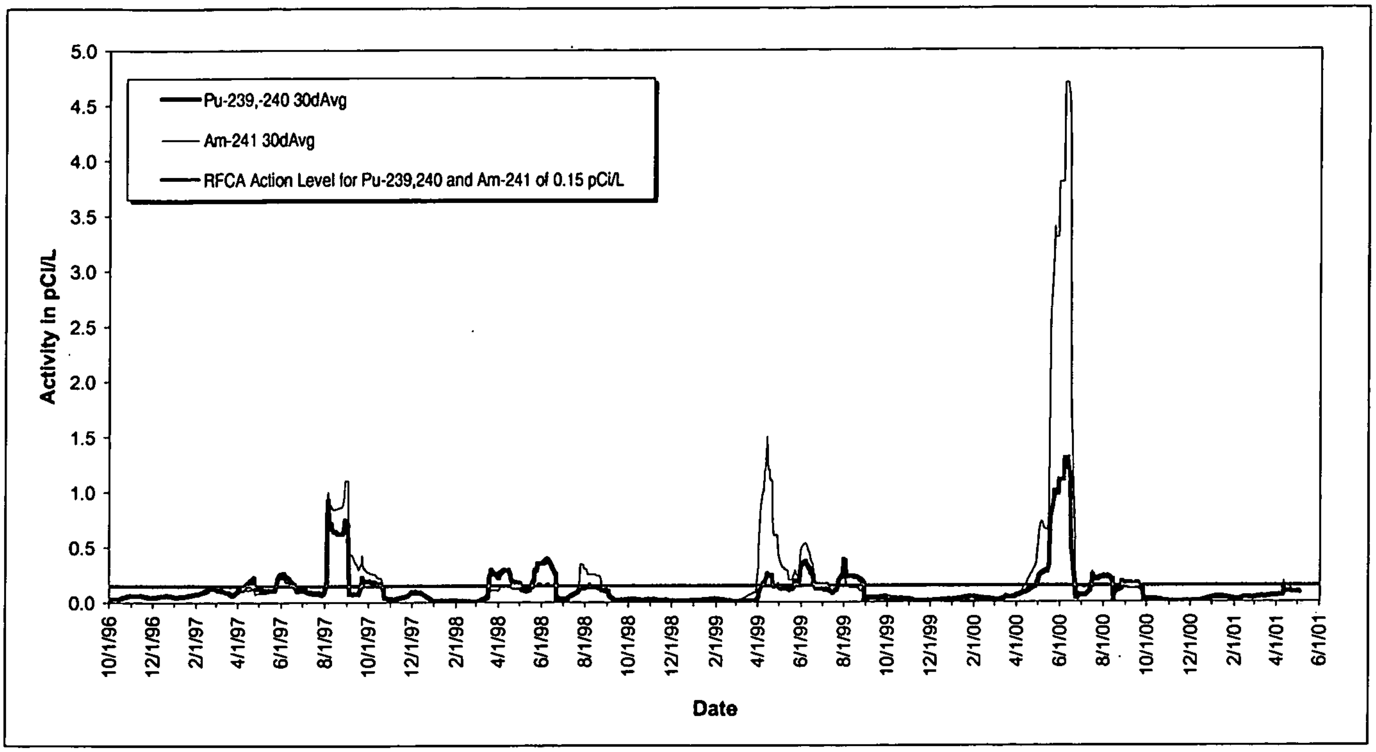


Figure 2-2. POE Gaging Station GS10: 30-Day Volume-Weighted Average Values for Pu and Am Activities (10/1/96 – 5/4/01).

2.0 and significant and verifiable deviations from these values suggest atypical source(s) "enriched" in Am. In the case of radionuclide data and Pu/Am ratios at GS10, significant deviations from typical Pu/Am ratios > 2, and (fractional) Pu/Am ratios < 1 are associated with recent elevated Pu and Am water-quality data. In fact, the Am levels at GS10 are often greater than the Pu levels.

[8] Storm-event samples are generally flow-paced composites consisting of 15 grab samples taken during a direct runoff hydrograph. The grab samples are targeted to be taken on the rising limb. This type of sampling was performed at GS10 from 4/93 through 9/30/96.

[9] Currently under RFCA, samples collected at POEs are continuous flow-paced composites where grab samples are collected during all flow conditions. This type of sampling began at POEs and POCs on 10/1/96.

14

Table 2-2. Composite Sample Analytical Results for GS10: March 17 – September 12, 2000.

Composite Sample Period	Pu-239,240 (pCi/l)		Am-241 (pCi/l)		Composite Sample Volume (Liters)	S. Walnut Cr. Discharge Volume During Sample Period (Mgals)
	Result	Error (±)	Result	Error (±)		
3/17-3/22/00	0.027	0.026	0.026	0.027	15.4	0.70
3/22-3/30/00	0.043	0.031	0.062	0.041	12.8	0.58
3/30-4/6/00	0.084	0.045	0.076	0.055	11.8	1.90
4/6-5/2/00	0.257	0.083	0.744	0.192	12.0	1.78
5/2-5/15/00	0.308	0.096	0.517	0.133	7.6	1.00
5/15-5/25/00	2.270	0.382	8.385	1.210	7.4	0.97
5/25-6/19/00	0.043	0.041	0.145	0.060	10.2	1.19
6/19-6/26/00	0.019	0.020	0.087	0.053	19.6	0.76
6/26-6/27/00	0.161	0.064	0.236	0.083	11.8	0.45
6/27-7/3/00	0.018	0.023	0.050	0.036	15.0	0.40
7/3-7/7/00	0.034	0.029	0.058	0.048	10.2	0.23
7/7-7/14/00	0.500	0.123	0.640	0.153	10.6	0.46
7/14-7/17/00	0.329	0.114	0.335	0.093	22.0	4.09
7/17-7/28/00	0.000	0.011	0.005	0.016	11.2	0.49
7/28-8/18/00	0.098	0.045	0.082	0.037	13.4	1.53
8/18-8/28/00	0.203	0.071	0.147	0.058	22.0	3.73
8/28-9/12/00	0.009	0.012	0.030	0.025	10.2	0.60
9/12-9/20/00	0.045	0.031	0.023	0.026	16.4	0.96

Notes: Activities greater than the Action Level are indicated in red.

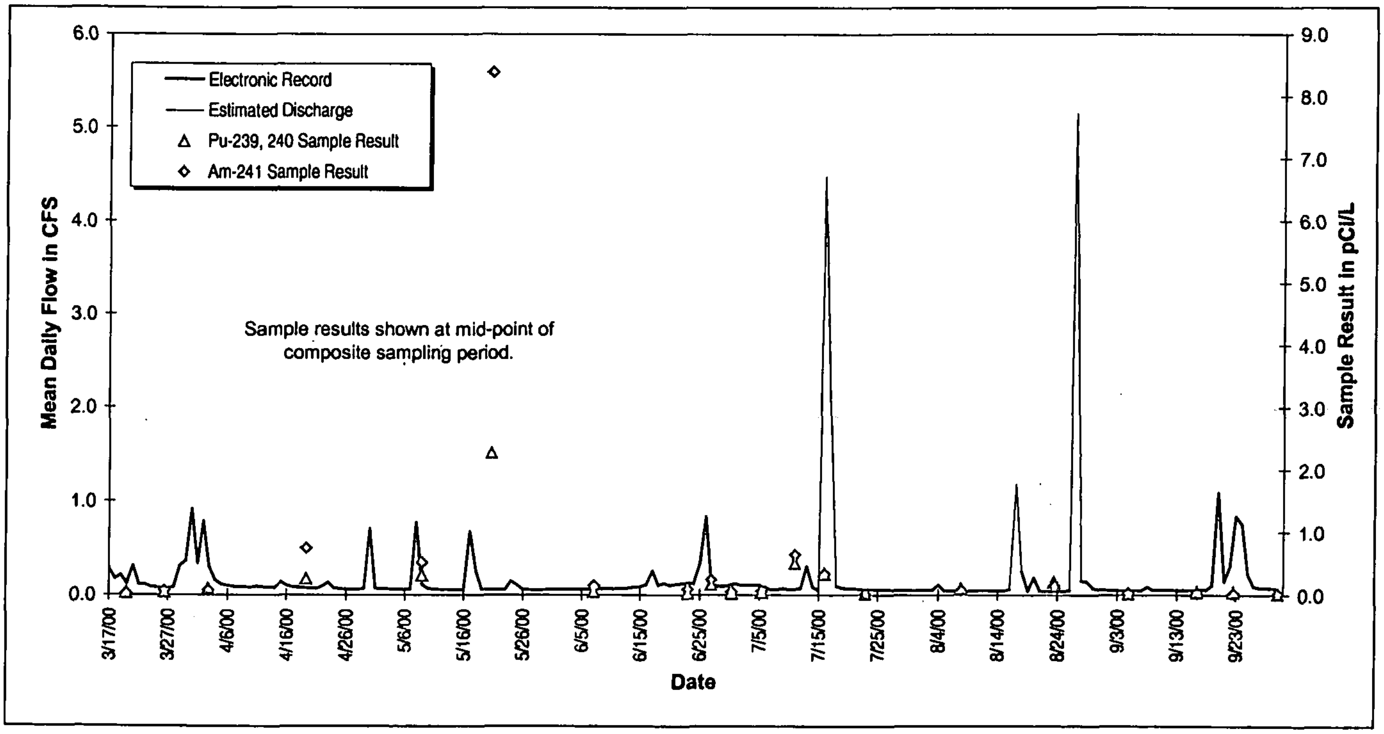


Figure 2-3. Gaging Station GS10 Hydrograph with Individual Sample Results: 3/17 – 10/1/00.

15

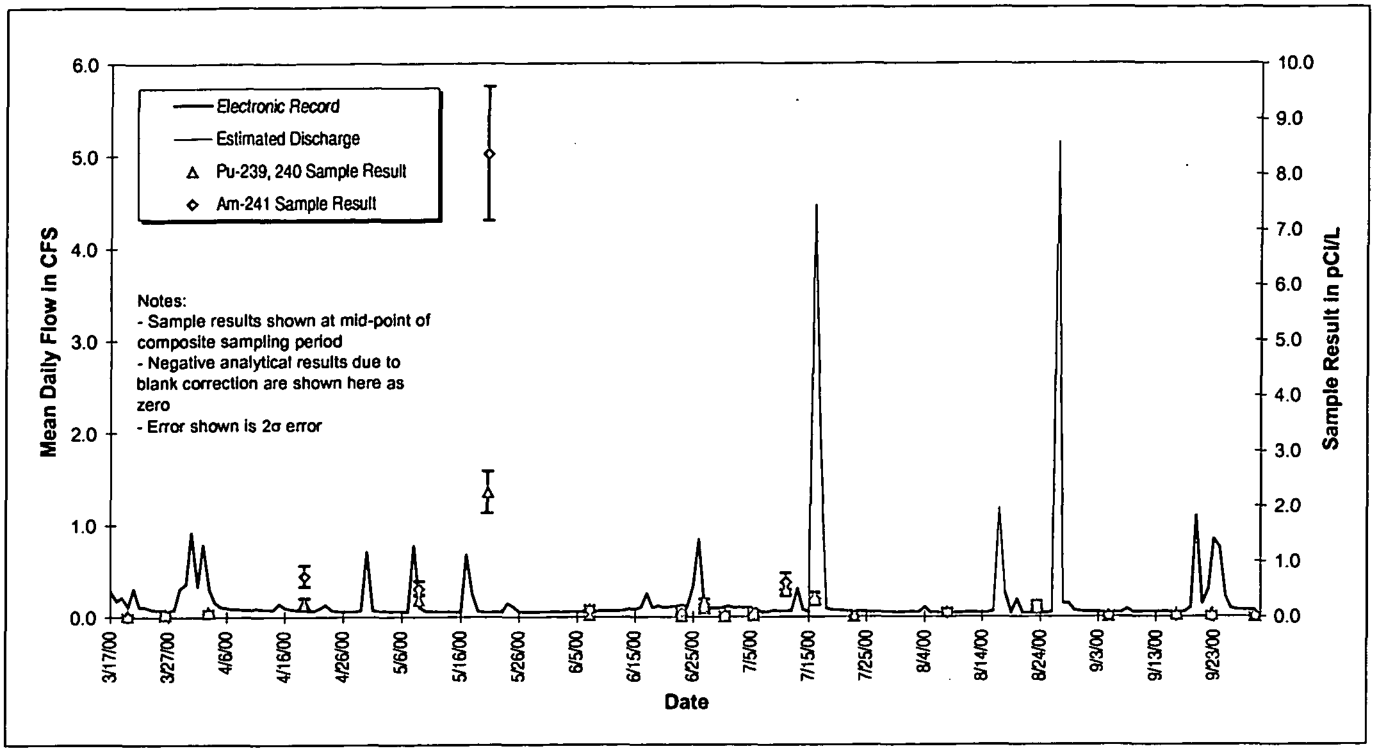


Figure 2-4. Gaging Station GS10 Hydrograph with Individual Sample Results and Error Bars: 3/17 – 10/1/00.

All water monitored at GS10 during this period flowed to Pond B-5 and was eventually direct discharged to lower Walnut Creek. Pre-discharge samples of the water in Pond B-5 indicated acceptable water quality prior to all planned discharges. However, a single analytical result from composite samples collected at POC gaging station GS08 (Pond B-5 outfall; Figure 2-1) during this period resulted in reportable 30-day average values (Figure 2-5). This reportable event is addressed in the *Source Evaluation Report for Point of Compliance GS08: Water Years 2000-2001* (RF/EMM/WP-01-002.UN), May 2001.

All water discharged from Pond B-5 to Walnut Creek subsequently flowed through RFCA POC GS03 at the eastern Site boundary. Analytical results from composite samples collected at GS03 during the period of interest were below the RFCA standard (Figure 2-6).

16

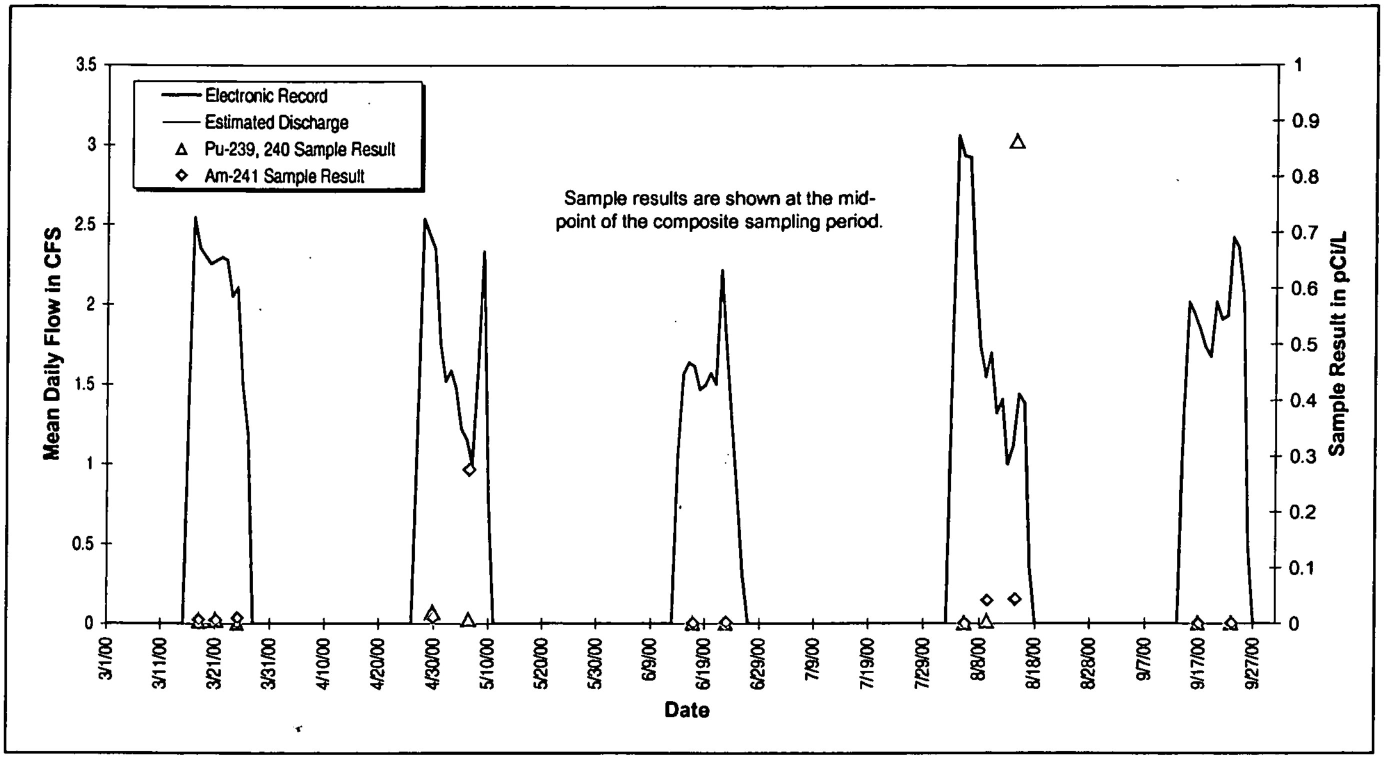


Figure 2-5. Gaging Station GS08 Hydrograph with Individual Sample Results: 3/1 – 10/1/00.

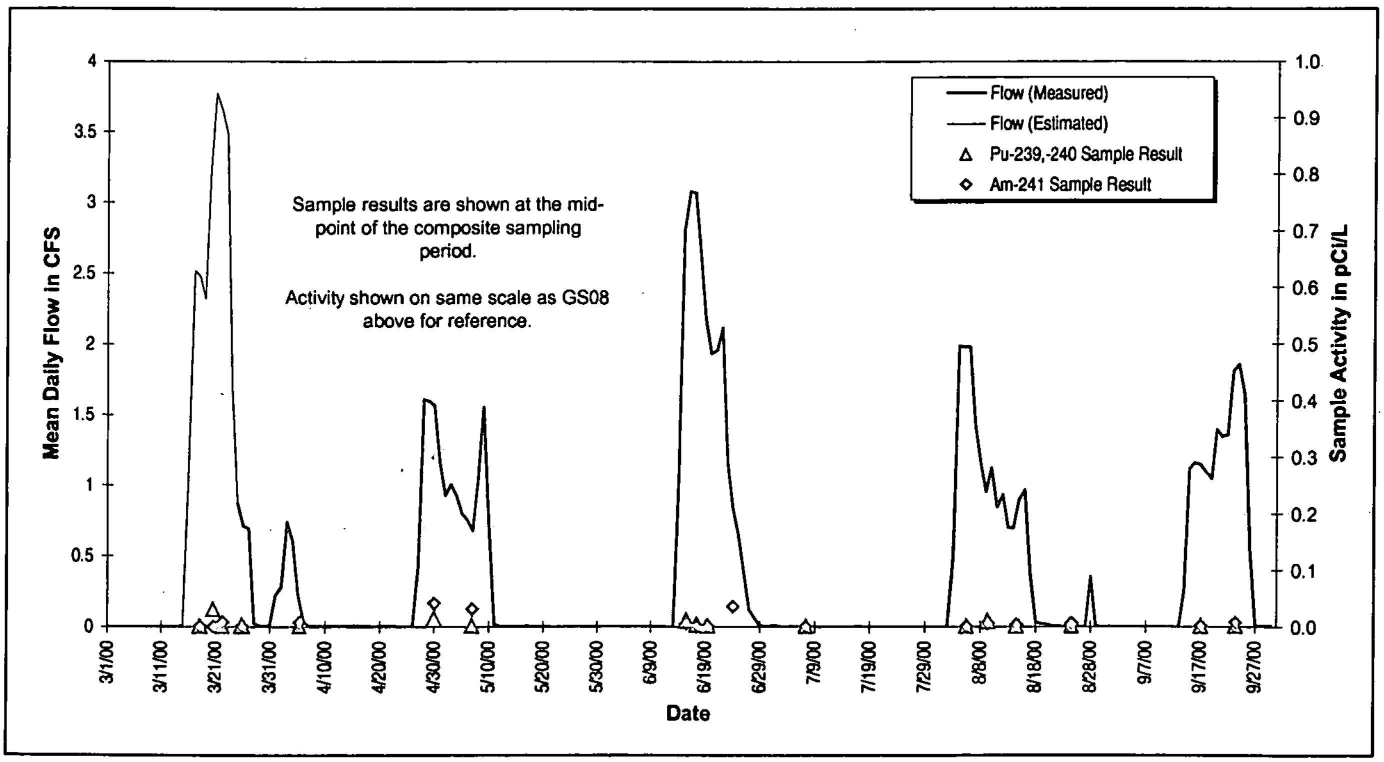


Figure 2-6. Gaging Station GS03 Hydrograph with Individual Sample Results: 3/1 – 10/1/00.

3 ACTINIDE MIGRATION EVALUATION

The AME is a program that provides an understanding of actinide migration and insight to the cause(s) and possible prevention of reportable radionuclide water-quality measurements. This multi-disciplinary study and the associated modeling initiative is key to understanding water-quality variability at the Site, and may eventually describe the extent and conditions under which Pu and Am are transported in the Rocky Flats environs. This section includes a discussion of AME progress and planned activities directly related to transport of actinides in surface water to provide background for Section 4 as related to this source investigation.

The AME is investigating processes that influence the movement of actinides associated with soils and sediments into stormwater runoff. Understanding these processes begins with a basic knowledge of the particle-size distribution of the actinides in soil and sediment, including the particle-size and actinide enrichment processes that occur when soil or sediment are eroded and suspended in runoff. Enrichment is the process whereby specific particle sizes of the parent soil become enriched in the suspended load in the runoff. Dr. James Ranville (Colorado School of Mines) and Dr. Peter Santschi (Texas A&M University) are investigating particle-size enrichment processes for the AME. Their work is integrated with stormwater monitoring and AME erosion/sediment transport modeling activities.

Ranville et al (1998), found that the enrichment ratio for clay- and silt-sized particles (less than 10 microns) is about 1.65. The ratio of the average activity on suspended particles measured in the GS42 runoff (30.8 pCi/g) to the average bulk soil Pu activity in the GS42 drainage basin (15.5 pCi/g) calculates to an enrichment ratio of 1.99. In other words, the activity per gram of the suspended solids is approximately twice that of the parent soil in the GS42 drainage basin. This evaluation has not been completed for the GS10 drainage basin due to the complexity of the basin, but the same mechanisms are suspected to influence actinide levels in the GS10 surface water. Texas A&M University will conduct actinide particle-size distribution experiments on GS27 soils in 2001.

The same enrichment phenomenon has been observed in the GS27 drainage basin, which is tributary to GS10. Particle enrichment is suspected to be the cause of high actinide concentrations in stormwater runoff from drainage basins with relatively low levels of soil contamination. Factors that enhance the enrichment process include wetting and suspension time, the total activity in the source soil or sediment, and contact with colloid-forming humic acids. However, it has been shown that contact with humic acids only increases actinide enrichment in the runoff by a fraction of a percent (Santschi et al, 2000). Dr. Peter Santschi is comparing the size distribution of actinides and the particle-size aggregation characteristics for soils from the GS27 and GS42 sub-drainages in FY01. Dr. Santschi is expected to deliver the results of his experiments for FY01 to the Site, and potentially to the stakeholders in October, 2001.

The enrichment process can also occur when the stream channel erodes. However, Site personnel do not have data to estimate the magnitude of the particle and actinide enrichment ratios for channel erosion. The AME HEC-6T sediment transport models were modified in FY01 to simulate the channel erosion process. The preliminary HEC-6T models for Walnut Creek indicate that channel erosion accounts for a majority of the suspended sediment concentration for a one-year return period (35mm rain in 11.5 hours, one-year event), but overland runoff and erosion contribute more sediment than channel erosion process for larger events (e.g. 97.1mm, 100-year, 6-hour event) (Table 3-1). AME has not done an analysis specifically for the GS10 drainage due the WEPP erosion model's inability to adequately represent industrial surfaces.

18

Table 3-1. Preliminary HEC-6T Model Estimated Channel Erosion Results for Walnut Creek.

Event Depth (mm)	Reach	Channel Erosion in Model?	Estimated Sediment Yield (kg)	Estimated Sediment Concentration (mg/L)	Portion of Yield Attributed to Channel Erosion (%)	Portion of Yield Attributed to Hillslope Erosion (%)
	South Walnut	Yes	16,831	183	5%	95%
		No	16,044	175		
100-Year, 6-Hour	No Name	Yes	38,982	1,390	45%	55%
97.1 mm		No	21,509	767		
	Indiana Street	Yes	157,189	557	12%	88%
		No	138,413	490		
	South Walnut	Yes	6,151	118	14%	86%
		No	5,289	101		
10-Year, 6-Hour	No Name	Yes	5,757	660	22%	78%
62.3 mm		No	4,512	517		
	Indiana Street	Yes	63,519	478	31%	69%
		No	43,761	329		
	South Walnut	Yes	5,018	277	12%	88%
		No	4,412	243		
17-May-95	No Name	Yes	11,345	748	80%	20%
74.9 mm		No	2,315	153		
	Indiana Street	Yes	48,996	469	20%	80%
		No	39,182	375		
	South Walnut	Yes	736	27	20%	80%
		No	588	21		
2-Year, 6-Hour	No Name	Yes	702	405	26%	74%
40.8 mm		No	517	298		
	Indiana Street	Yes	14,351	245	89%	11%
		No	1,514	26		
	South Walnut	Yes	474	22	55%	45%
		No	213	10		
2-Year, 2-Hour	No Name	Yes	572	680	54%	46%
31.5 mm		No	262	312		
	Indiana Street	Yes	18,211	426	97%	3%
		No	576	13		
	South Walnut	Yes	22	5	50%	50%
		No	11	2		
1-Year, 11.5-Hour	No Name	Yes	173	129	57%	43%
35 mm		No	75	56		
	Indiana Street	Yes	8,095	448	96%	4%
		No	342	19		

Note: The South Walnut stream reach runs from the IA through GS08 (Pond B-5 outlet). The No Name reach runs the length of No Name Gulch from the Landfill Pond to the confluence with Walnut Creek. The Indiana Street stream reach covers all of Walnut Creek from the IA to Indiana Street including No Name Gulch.

At the Health Physics Society 2000 Conference in Denver (August 2000), Povetko and Higley presented a poster titled "Study of Particles of Actinides in Soil Samples Using Nuclear Track Detectors." Their work used a soil sample from near the 903 Pad at RFETS. The investigators identified 990 discrete Pu-containing particles that included several large (greater than 2 microns) conglomerate particles containing Pu and Am. One such conglomerate with a particle size of about 500 microns contained 1.87 Bq (50.5pCi) or 94% of the total recorded alpha activity of 1.98 Bq in all 990 particles. In other words, the conglomerate contained 94% of the sample Pu, while the other 989 particles contained the remaining 6%.

19

The investigators' conclusions support the hypothesis that the Pu in soils is not evenly distributed amongst particle sizes. A majority of the total activity is associated with particular size fractions (and/or individual particles) of the total soil mass. Therefore, if these particles were preferentially suspended as total suspended solids (TSS), an enrichment of Pu activity in surface water would result. Additionally, the variable distribution of these high-activity particles could result in variable measured surface-water activities based on the probability that these particles may or may not be collected in the sample bottle.

4 DATA SUMMARY AND ANALYSIS

The following data evaluation includes all surface-water data available as of 6/20/01.[10] Monitoring data were extracted from the Site Soil-Water Database (SWD) or taken from hardcopy analysis reports for the locations of interest. The following list describes the environmental data compilation process:

- Individual sample result values are calculated as arithmetic averages of real and field duplicate results when both results are from the same sampling event;
- When available, laboratory re-runs are averaged with initial runs for the same sampling event;
- Laboratory duplicate and replicate QC results are not used;
- When negative values for actinide measurement are returned from the laboratories due to blank correction, 0.0 pCi/l is used in the calculations;
- When TSS (total suspended solids) and metals values are qualified by the laboratories as 'undetect', half the detection limit is used in calculations, unless indicated otherwise;
- Only total radionuclide measurements are used; and
- Data that did not pass validation (rejected data) are not used.

4.1 Verification and Validation of Surface-Water Analytical Results

All surface water isotopic data are either verified or validated, based on criteria determined by Analytical Services Division (ASD), or at the special request of the customer. Approximately 75% of all isotopic data are verified and the remaining 25% are validated. Validation is typically determined randomly for each subcontracted laboratory, based on the specific analytical suites. This random validation selection may or may not routinely include POE or POC locations. However, when reportable values are observed, all analytical results used in the calculations receive formal validation.

For samples collected at GS10 for 3/17/00 - 9/20/00 and 2/28/01 – 4/19/01 all isotopic data not randomly selected for validation were specifically submitted for validation at the request of Site personnel. All isotopic data package validation was performed by a subcontractor to ASD, and all packages in the date range identified were considered valid.

20

4.2 Automated Surface-Water Monitoring Data

4.2.1 Analytical Data Summary

Surface-Water Activities

Since March 3, 1998, five upstream automated monitoring locations have been operating as part of the continuing source evaluation for GS10 as a response action to reportable Pu and Am measurements during WY97. These locations are GS27, GS38, GS39, GS40 and SW022 (Figure 4-1). GS43 was installed on June 1, 1999, and GS50 was installed on March 28, 2001. These stations were installed or upgraded to monitor sub-drainages that are tributary to GS10.[11] These locations are operated to characterize water quality and specifically measure Pu and Am loads from the respective sub-drainages in an attempt to identify any discrete source areas. Summary statistics for sample results from these locations are shown in Table 4-1. The activities for GS27 and SW022[12] are arithmetic averages since these locations have historically sampled only selected storm events. Continuous flow-paced sampling is used for GS10, GS38, GS39, GS40, GS43, and GS50 and volume-weighted average activities are given in Table 4-1.

Table 4-1. Summary Statistics for Samples from GS10 and Monitoring Locations Tributary to GS10: March 3, 1998 to Present.

Sampling Location	Number of Samples	Pu-239,-240		Am-241	
		Average Activity (pCi/l)	Maximum Sample Result (pCi/l)	Average Activity (pCi/l)	Maximum Sample Result (pCi/l)
GS10	105	0.156	2.270	0.245	8.385
GS27	39	6.034	64.30	1.536	14.800
GS38	33	0.088	0.307	0.021	0.077
GS39	32	0.138	0.825	0.035	0.160
GS40	40	0.021	0.085	0.039	0.140
GS43	10	0.018	0.028	0.002	0.018
GS50	2	0.099	0.197	0.131	0.180
SW022	37	0.500	9.490	0.102	1.760

Notes: Includes all data available as of 6/20/01. Data for GS43 starts on 6/1/99; data for GS50 starts on 4/12/01.

---

[10] Surface-water data for GS10 includes co-located monitoring locations SW67593 and SW68893 (OU6 sample locations). Evaluations are performed using various data subsets. These subsets are defined in the text or in notes below each figure/table.

[11] GS39, GS40, GS43, and GS50 also serve as a Performance monitoring locations in support of remedial activities for the 903 Pad, the 700 Area, B886, and the Solar Ponds, respectively. SW022 also serves as a New Source Detection monitoring location as specified by the IMP.

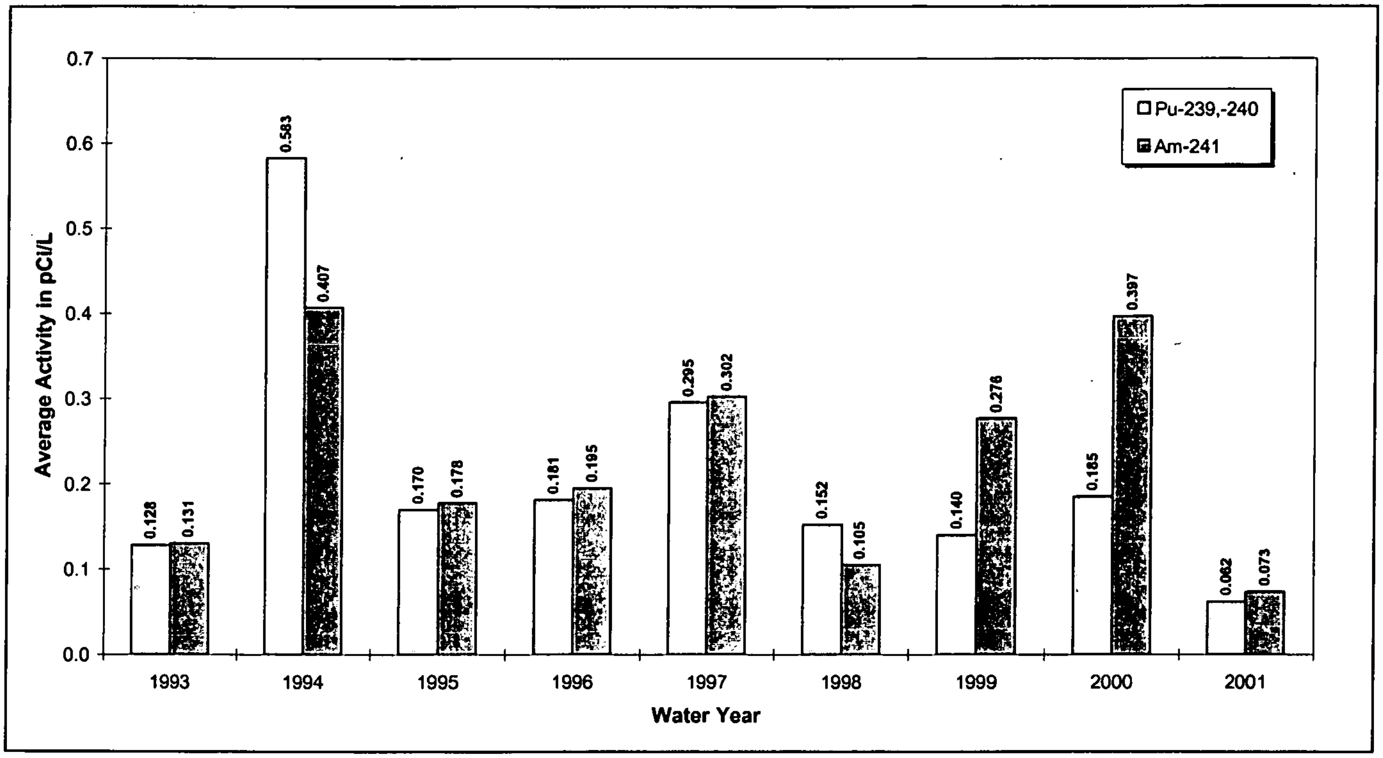
[12] Starting on 10/1/99, SW022 was converted to collect continuous flow-paced samples. The average shown in Table 4-1 is the arithmetic average of results from both types of samples. The average also includes storm-event samples collected during WY2000-2001 as part of the automated synoptic sampling activities.

21

Figure 4-1. Automated Surface Water Monitoring Locations and Corresponding Sub-Drainage Areas Tributary to GS10.

See attached map.

Figure 4-2 shows the average annual activities at GS10 for WY93 – WY01. For WY93 - WY96, arithmetic averages of individual storm-event sample results are plotted. However, due to the continuous flow-paced sampling protocols currently in place under RFCA, the more representative volume-weighted average activities are shown for WY97-WY01. It is important to note that although elevated 30-day average values occurred in recent years, the volume-weighted average is comparable to the activities for other years. This suggests that actinides have been available for transport to GS10 for some time and that the recent measurements at GS10 are likely the result of legacy contamination. The unusual Pu/Am ratios are evaluated in greater detail in Section 4.2.3.



Volume-weighted to activity through 5/4/01 for WY01 is plotted.

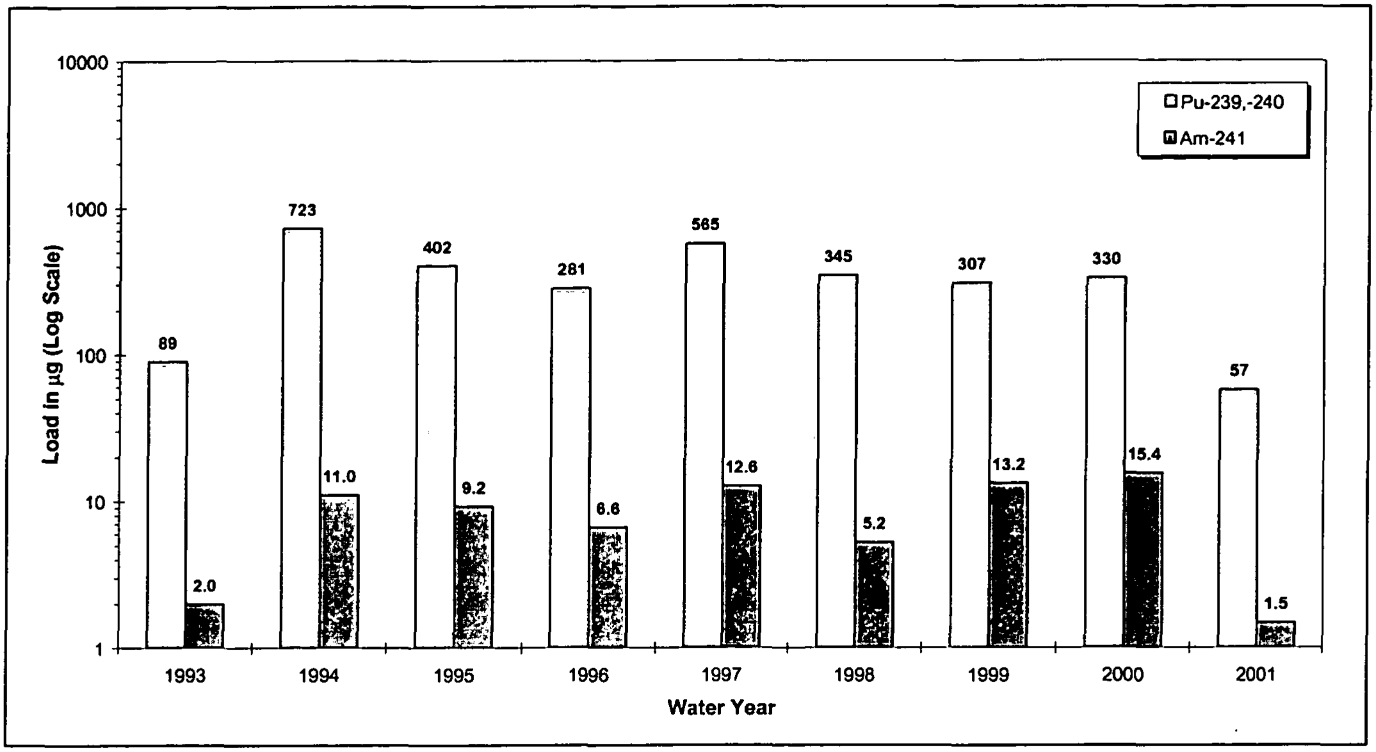
Figure 4-2. Average Annual Pu and Am Activities at GS10: Water Years 1993-2001.

Annual GS10 Loads

Annual radionuclide loads for GS10 in micrograms are plotted in Figure 4-3 to show long term loading to GS10. For WY93 - WY96, the arithmetic average activity of individual sample results is multiplied by the associated total annual discharge volume to get pCi, then converted to micrograms[13]. For WY97-WY01, the activity for each flow-paced composite sample is multiplied by the associated discharge volume to get pCi, then converted to micrograms

[13] Picocuries of plutonium are multiplied by 14.085 to get picograms, and divided by 10^6 to get micrograms. Similarly, picocuries of americium are multiplied by 0.3077 to get picograms, and divided by 10^6 to get micrograms.

and summed.[14] As stated previously, this suggests that actinides have been available for transport to GS10 for some time and that the recent measurements at GS10 are likely the result of legacy contamination.



Load through 5/4/01 for WY01 is plotted.

Figure 4-3. Annual Pu and Am Loads at GS10: Water Years 1993-2001.

4.2.2 Relative Loading Analysis

This loading analysis uses data from all automated monitoring locations that are tributary to GS10 (Figure 4-1). These locations are GS27, GS38, GS39, GS40, GS43, and SW022.[15] The analysis is performed for two overlapping time periods based on the operational periods for two groups of locations. For the first period, 3/3/98 to date,

[14] Storm-event samples are generally flow-paced composites consisting of 15 grabs taken during a direct runoff hydrograph and not during baseflow conditions. The grabs are targeted to be taken on the rising limb of a runoff period as flow rates increase to the peak. This is the period during direct runoff when the highest contaminant concentrations are expected to be measured. Under RFCA (starting 10/1/96), samples collected at POEs are continuous flow-paced composites where grab samples are collected during all flow conditions.

[15] GS50 began sampling on 4/12/01, and is not included in the loading analysis.

monitoring locations GS27, GS38, GS39, GS40, and SW022 were all operational. For the second period, 10/1/99 to date, monitoring locations GS27, GS38, GS39, GS40, GS43, and SW022 were all operational.[16]

The 100, 300, 400, 500, 600, 800, and 900 Areas all contribute runoff to SW022 via the Central Ave. Ditch. During high flows, a portion of the flow in the Central Avenue Ditch overflows to a 48-inch pipe which leads directly to South Walnut Creek, bypassing SW022, as indicated by the dotted flow line in Figure 4-4. This upstream flow bypass causes the calculated load for SW022 to be an underestimate of the total Central Avenue Ditch sub-drainage area contribution to GS10.

Table 4-2 gives location and drainage basin detail for the monitoring locations used in this loading analysis. The hydrologic connectivity of these locations is shown in Figure 4-4 and Figure 4-7.

Table 4-2. Location and Drainage Basin Detail (GS10, GS27, GS38, GS39, GS40, GS43, and SW022).

Location Code	Location Detail	Contributing Areas
GS10	S. Walnut Cr. 40 feet upstream of the B-1 Bypass	100, 300, 400, 500, 600, 700, 800, 900; 167.2 acres
GS27	Drainage ditch NW of B884	Area south and west of B884; 0.4 acres
GS38	Central Ave. Ditch at 8th Street	100, 300, 400, 500, 600; 41.3 acres
GS39	Drainage ditch N of 904 Pad	903 Pad, 904 Pad, Contractor Yard; 8.1 acres
GS40	Culvert E of 750 pad draining 700 Area to S. Walnut Cr.	700; 24.5 acres
GS43	Drainage ditch NE of B886	B886 area; 1.1 acres
SW022	East end of Central Ave. Ditch at Inner East Fence	100, 300, 400, 500, 600, 800, 900; 76.8 acres

After the initiation of continuous flow-paced sampling on 10/1/99 at SW022, loads for SW022 were calculated by multiplying the activity for each flow-paced composite sample by the associated discharge volume to get pCi, then converted to micrograms.[17] The load for any period is then the sum of the individual sample loads during that period. Loads for GS10, GS38, GS39, GS40, and GS43 continuous flow-paced samples were calculated in an identical fashion.

For SW022 data prior to 10/1/99 (storm-event samples), loads for any period are calculated by multiplying an estimated overall activity by the corresponding discharge measured at the gage, and then converting to

---

[16] GS43 was installed on 6/3/99. Additionally, sampling protocols at SW022 were changed from storm-event sampling to continuous flow-paced sampling on 10/1/99. Therefore, the period 10/1/99 to date was chosen for the second analysis period.

[17] Continuous flow-paced composite samples are collected continuously during all flow conditions. Consequently, the analytical result is assumed to be representative of the overall water quality for each sampling period.

micrograms.[18] Loads for the GS27 sub-drainage were calculated by the same method using the storm-event sample results from GS27. The following methods were used to estimate a range of loads for SW022 and GS27:

- The annual arithmetic average activity is multiplied by the corresponding measured annual discharge volume to estimate annual loads. The annual loads are then totaled for the analysis period.[19]
- The overall seasonal arithmetic average activity is multiplied by the corresponding measured total seasonal discharge volume to estimate seasonal loads. The seasonal loads are then totaled for the analysis period.
- The arithmetic average activity for the entire analysis period is multiplied by the corresponding measured discharge volume to estimate the total load for the analysis period.
- The minimum variance unbiased (MVU) estimator of the mean activity for the entire analysis period is multiplied by the corresponding measured discharge volume to estimate the total load for the analysis period.[20]

The loads estimated for SW022 and GS27 are summarized in the following analysis by using the minimum and maximum estimated loads from the various methods.

Relative Sub-Drainage Loads: March 3, 1998 to Date

The loading analysis in this section uses all available data for the period 3/3/98 through 5/4/01 from GS10 and the five upstream Source Location monitoring stations (GS27, GS38, GS39, GS40 and SW022). This loading analysis does not address the attenuation of actinides as they are transported from one monitoring location to the next. The analysis assumes that as the period of sampling is increased, the temporal effects of actinide transport will not significantly affect the relative loads from the various sub-drainages. The hydrologic connectivity of these locations is shown in Figure 4-4.

---

[18] Storm-event sampling collects samples during the rising limb of a direct runoff hydrograph following a precipitation event. The highest TSS measurements, and corresponding Pu and Am activities, are typically measured during these hydrologic conditions. Therefore, simple arithmetic average activities using these sample results would be expected to be biased high relative to the 'true' mean activity for a given location. Additionally, actinide water-quality variation tends to be lognormal, and also varies with flow rate, season, storm size, and time. Therefore, various activity estimation techniques and periods are used to calculate a range of estimated loads.

[19] As stated previously, two analysis periods were used based on the operation dates of the monitoring locations: 3/3/98 to date, and 10/1/99 to date.

[20] The MVU is calculated after first confirming that the sample results are from a lognormal distribution. The sample population is tested for lognormality using the *W* Test from Shapiro and Wilk when $n \leq 50$ or D'Agostino's Test when $n \geq 50$ (Gilbert, 1987).

21

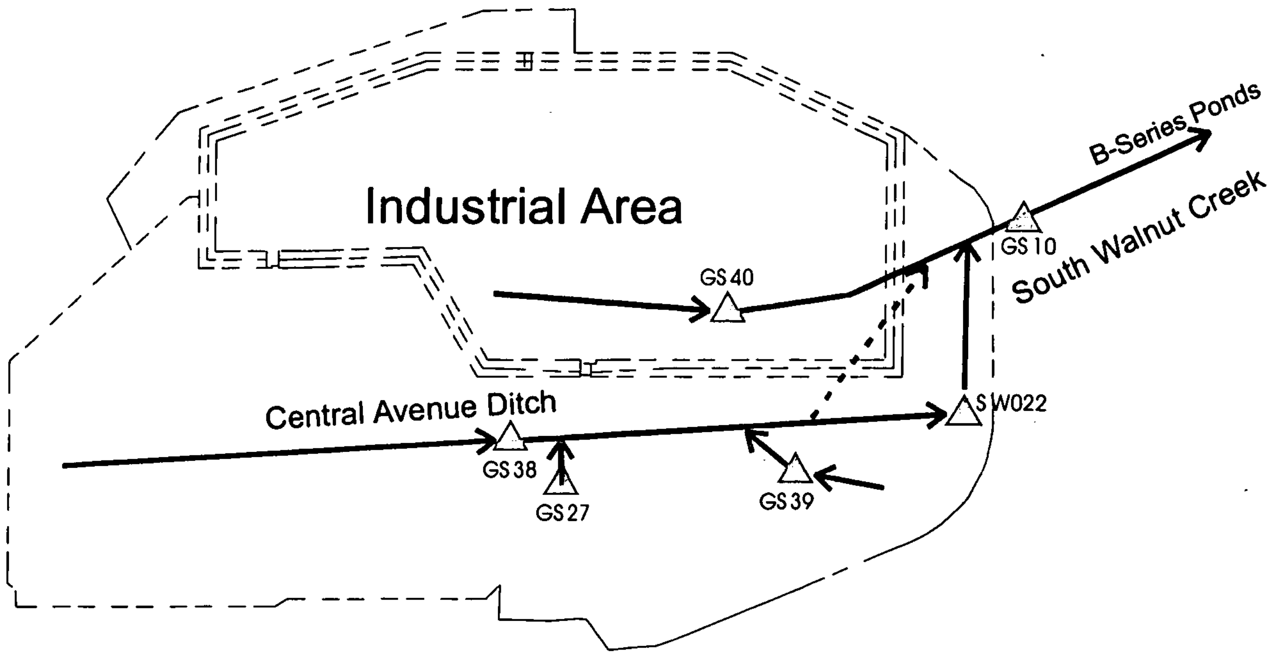


Figure 4-4. Hydrologic Connectivity of Monitoring Locations Tributary to GS10 (as of 3/3/98).

Table 4-3 and Figure 4-5 indicate that the Central Ave. Ditch sub-drainage (as measured by SW022) is contributing a significant portion of the Pu load measured at GS10. However, this load may be an overestimation of the actual loads from this sub-drainage due to the use of sample results from storm-events (collected at SW022 prior to 10/1/99). The storm-event sampling protocols result in the preferential collection of samples during high runoff events with relatively high activities (higher TSS transport). Therefore, the activity for storm-event samples is likely higher than the actual overall activity for all flow conditions. Conversely, the partial bypassing of high flows from Central Ave. Ditch directly to GS10 would cause the load at SW022 to be an underestimation of the total load from the Central Ave. Ditch sub-drainage area. Continuous flow-paced sampling facilitates more accurate loading analysis through the collection of representative samples over all flow conditions.

Table 4-3. Comparison of Plutonium and Americium Loads at Tributary Locations with GS10: 3/3/98 through 5/4/01.

Location	Pu-239,-240 Load in µg	Am-241 Load in µg
GS10	1015.7	34.89

Location	Pu-239,-240		Am-241	
	Load in µg	Load as a Percent of GS10 Load	Load in µg	Load as a Percent of GS10 Load
SW022	392.9 – 880.9	39% – 87%	1.68 – 3.99	4.8% - 11%
GS40	51.3	5.1%	2.02	5.8%
GS39	23.9	2.4%	0.13	0.4%
GS27	62.2 – 68.5	6.1% - 6.7%	0.29 – 0.38	0.8% - 1.1%
GS38	83.9	8.3%	0.44	1.3%

28

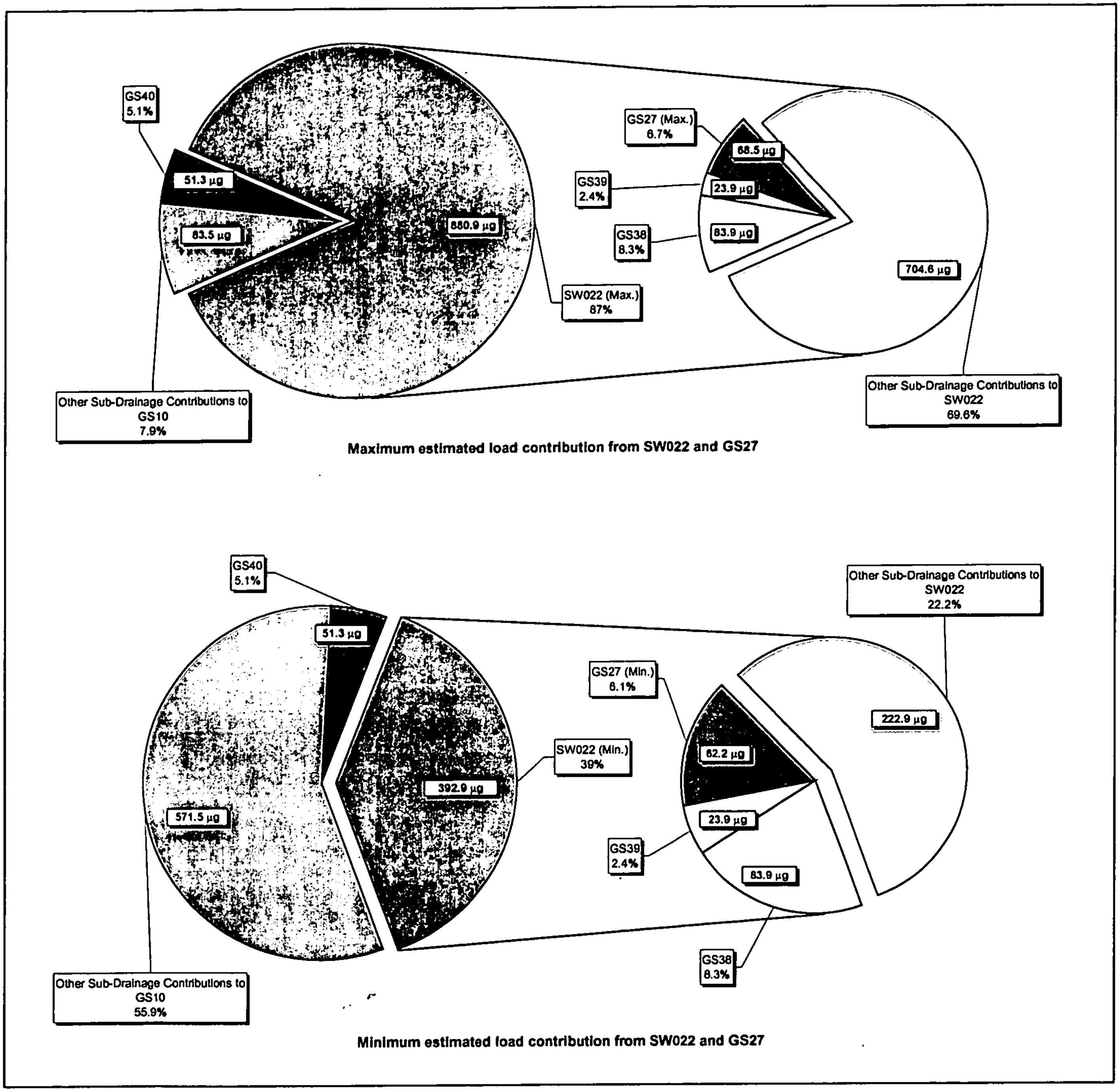


Figure 4-5. Relative Plutonium Load Contributions from Locations Tributary to GS10: 3/3/98 through 5/4/01.

29

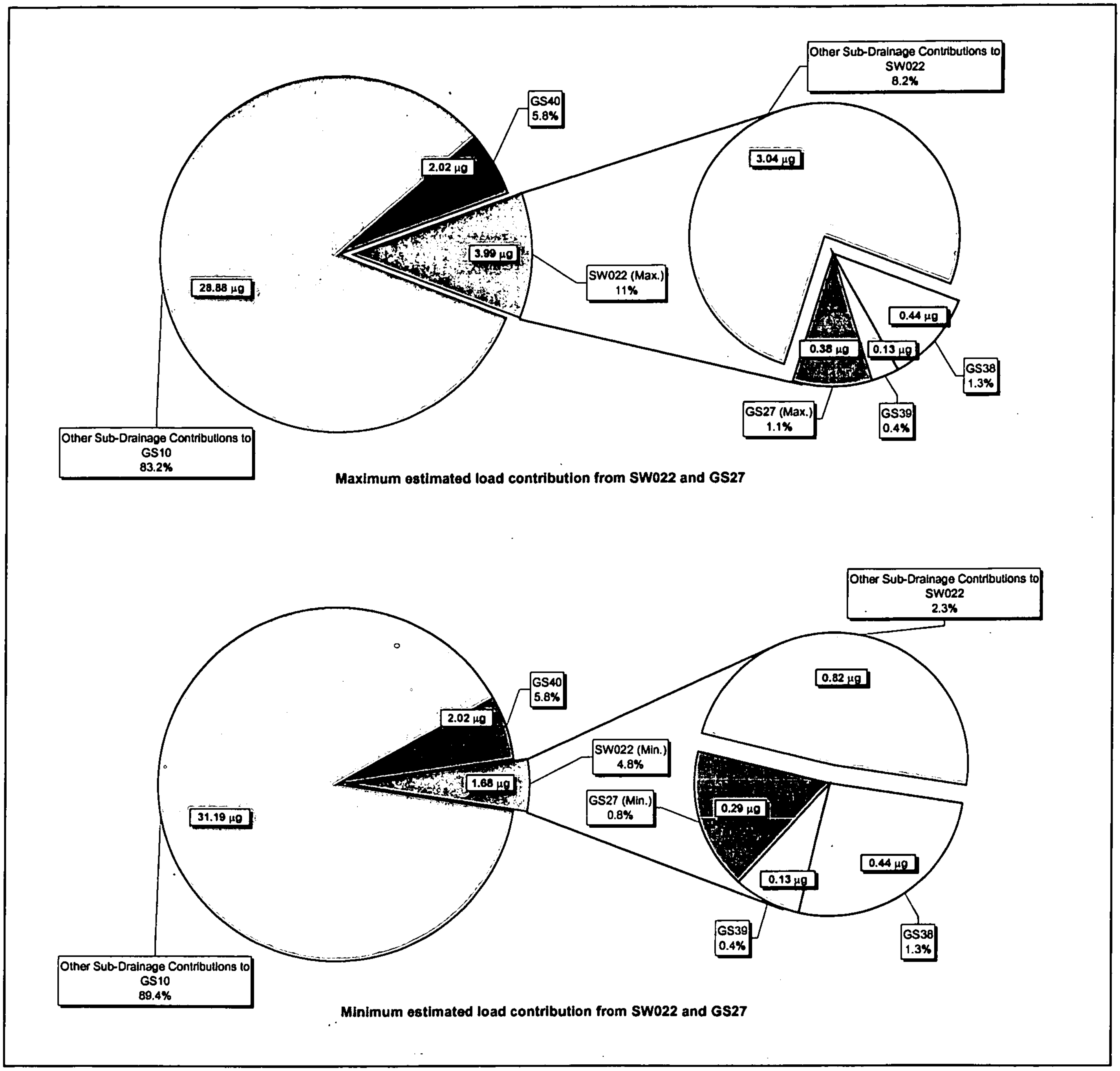


Figure 4-6. Relative Americium Load Contributions from Locations Tributary to GS10: 3/3/98 through 5/4/01.

Table 4-3 and Figure 4-6 indicate that the Central Ave. Ditch sub-drainage (as measured at SW022) contributed a small portion of the Am load measured at GS10. This suggests that the majority of the Am load at GS10 originates from tributary areas other than the Central Ave. Ditch sub-drainage. Additionally, the Am load attributed to the GS40 sub-drainage (Figure 4-1) is estimated at only 6% of the load at GS10. This suggests that a source of Am may exist in the sub-drainage area downstream of both SW022 and GS40, specifically within the reach of S.

Walnut Cr. between the 750 Pad and GS10. Additional information evaluated in the following sections of this report support this hypothesis of a source 'enriched'[21] in Am in this stream reach.

Table 4-3 and Figure 4-5 indicate that the GS27, GS38, GS39, and GS40 sub-drainages contribute up to 23% of the Pu load reaching GS10. Therefore, other sub-drainages not specifically monitored are estimated to contribute the remaining 77% of the Pu load measured at GS10 (788 µg Pu). These areas include (see Figure 4-1) the S. Walnut Cr. reach between GS40 and GS10 (B991 is in this sub-drainage), a portion of the 500 Area outside the Protected Area (PA), portions of the 800 Area, and the Central Ave. Ditch reach between GS38 and SW022 (Trench T-1 and the Mound Area are in this sub-drainage). The fact that SW022 samples have shown relatively high Pu activities, coupled with the proximity of the 903 Pad, suggests that the Central Avenue Ditch reach between GS38 and SW022 might contain a significant distributed source of Pu. Surface-soil and sediment data for these areas are evaluated in Section 4.4.

Table 4-3 and Figure 4-6 indicate that the GS27, GS38, GS39, and GS40 sub-drainages contribute only 9% of the Am load reaching GS10. Therefore, other sub-drainages not specifically monitored are estimated to contribute the remaining 91% of the Am load measured at GS10 (32 µg Am). These areas include the S. Walnut Cr. reach between GS40 and GS10, a portion of the 500 Area outside the PA, portions of the 800 Area, and the Central Ave. Ditch reach between GS38 and SW022.

The Am load evaluation also indicates that the SW022 sub-drainage (with includes GS27, GS38, and GS39) contributes up to 11% of the Am load to GS10, with an additional 6% being contributed from the GS40 sub-drainage. This further suggests that the S. Walnut Cr. reach between the 750 Pad and GS10 and/or a portion of the 500 Area outside the PA may contain a significant source of Am. Surface-soil and sediment data for these areas are evaluated in Section 4.4.

Relative Sub-Drainage Loads: October 1, 1999 to Date

The loading analysis in this section uses all available data for the period 10/1/99 through 5/4/01 from GS10 and the six upstream Source Location monitoring stations (GS27, GS38, GS39, GS40, GS43 and SW022) operating during this period. This loading analysis is performed as described for the loading analysis in the previous section. The purpose of this second analysis period is to provide a more accurate estimate of the SW022 sub-drainage loads using only continuous flow-paced sample results. The hydrologic connectivity of these locations is shown in Figure 4-7.

[21] The term 'enriched' is used in this document to identify source terms where Am activities are higher than predicted given the corresponding Pu activity. The expected ratios are based on the material that was historically used at the Site.

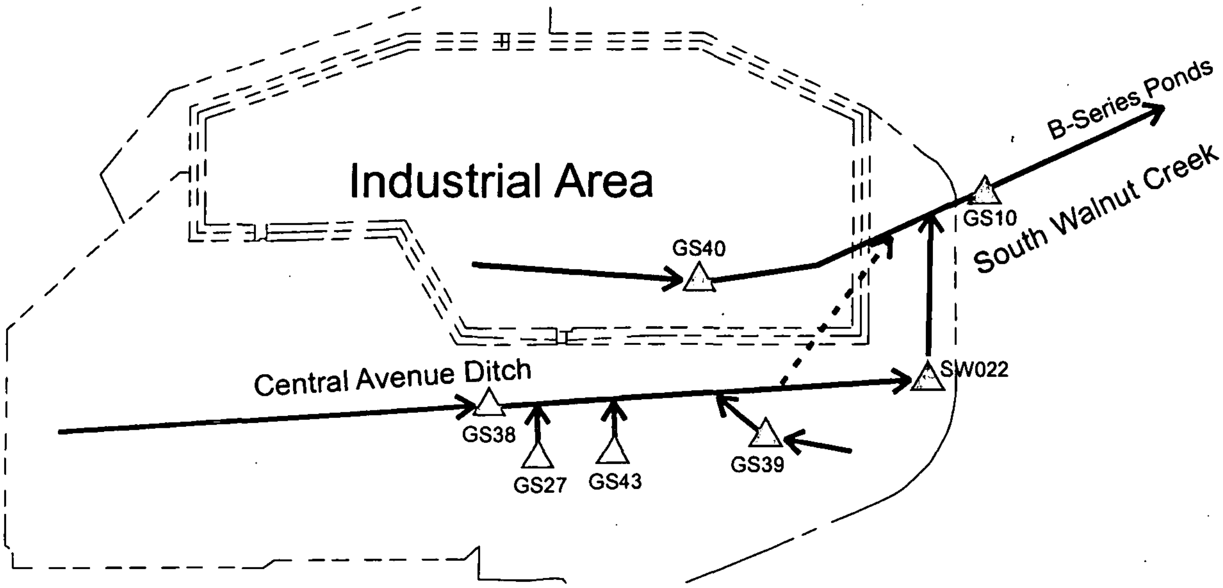


Figure 4-7. Hydrologic Connectivity of Monitoring Locations Tributary to GS10 (as of 10/1/99).

Table 4-4, Figure 4-8, and Figure 4-9 show the relative loads contributed by GS27, GS38, GS39, and GS40 to GS10 during the second analysis period (10/1/99 – 5/4/01) are similar to the loads during the first analysis period (3/3/98 – 5/4/01).[22] However, the relative loads at SW022 (using continuous flow-paced sample results) are significantly smaller. The combined loads from SW022 and GS40 are only a small proportion of the GS10 loads (26% of the Pu and 9% of the Am loads). Surface-water data from SW060 and soil/sediment data discussed in Sections 4.3 and 4.4 indicate that the unmonitored portion of the 500 Area is not a significant load contributor. Therefore, the sub-drainage area between GS40 and GS10 appears to contribute 74% of the Pu and 91% of the Am loads to GS10.

Table 4-4. Comparison of Plutonium and Americium Loads at Tributary Locations with GS10: 10/1/99 through 5/4/01.

Location	Pu-239,-240 Load in μg	Am-241 Load in μg
GS10	386.6	16.91

Location	Pu-239,-240		Am-241	
	Load in μg	Load as a Percent of GS10 Load	Load in μg	Load as a Percent of SW093 Load
SW022	69.2	17.9%	0.34	2.0%
GS40	30.7	7.9%	1.15	6.8%
GS39	6.3	1.6%	0.03	0.2%
GS43	0.2	0.1%	~0.0	~0%
GS27	3.6 – 5.1	1% - 1.3%	0.01 – 0.02	~0.1%
GS38	28.0	7.2%	0.11	0.7%

[22] Loads from GS43 are estimated to be <1% relative to GS10.

32

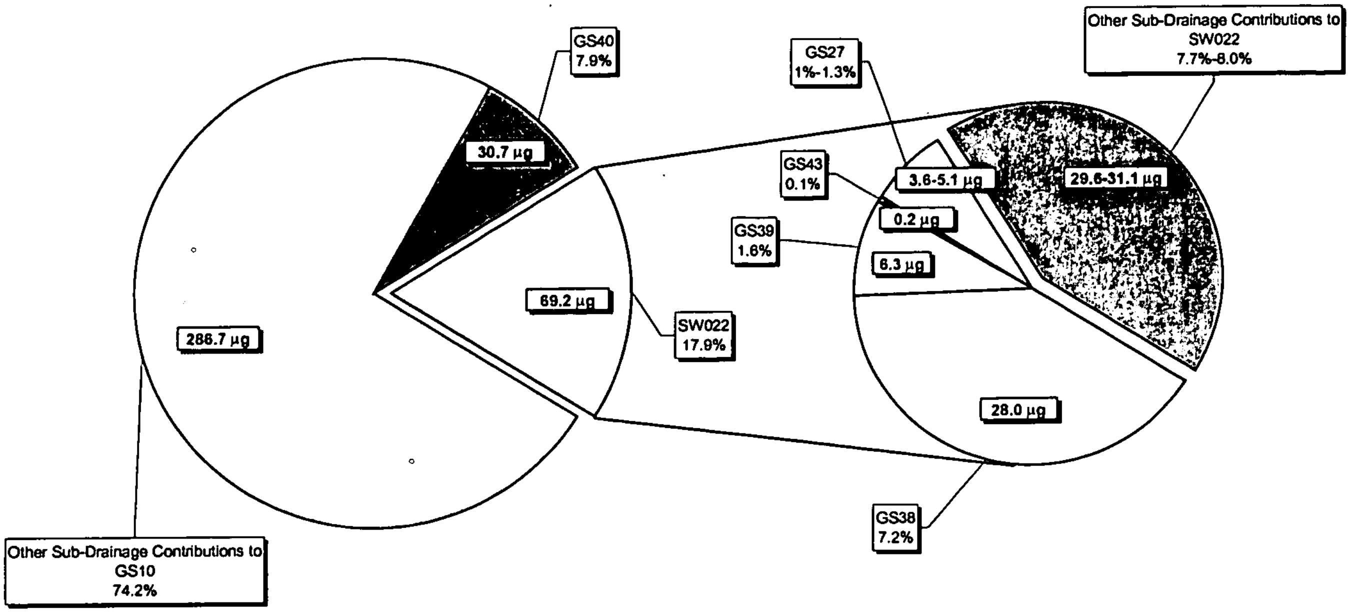


Figure 4-8. Relative Plutonium Load Contributions from Locations Tributary to GS10: 10/1/99 through 5/4/01.

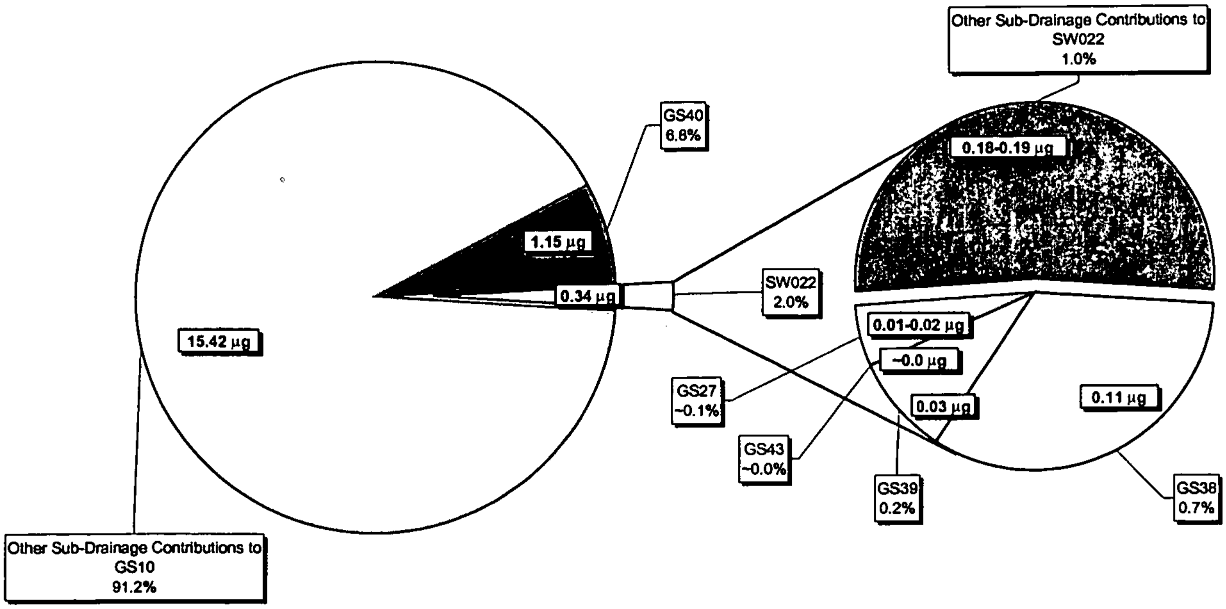


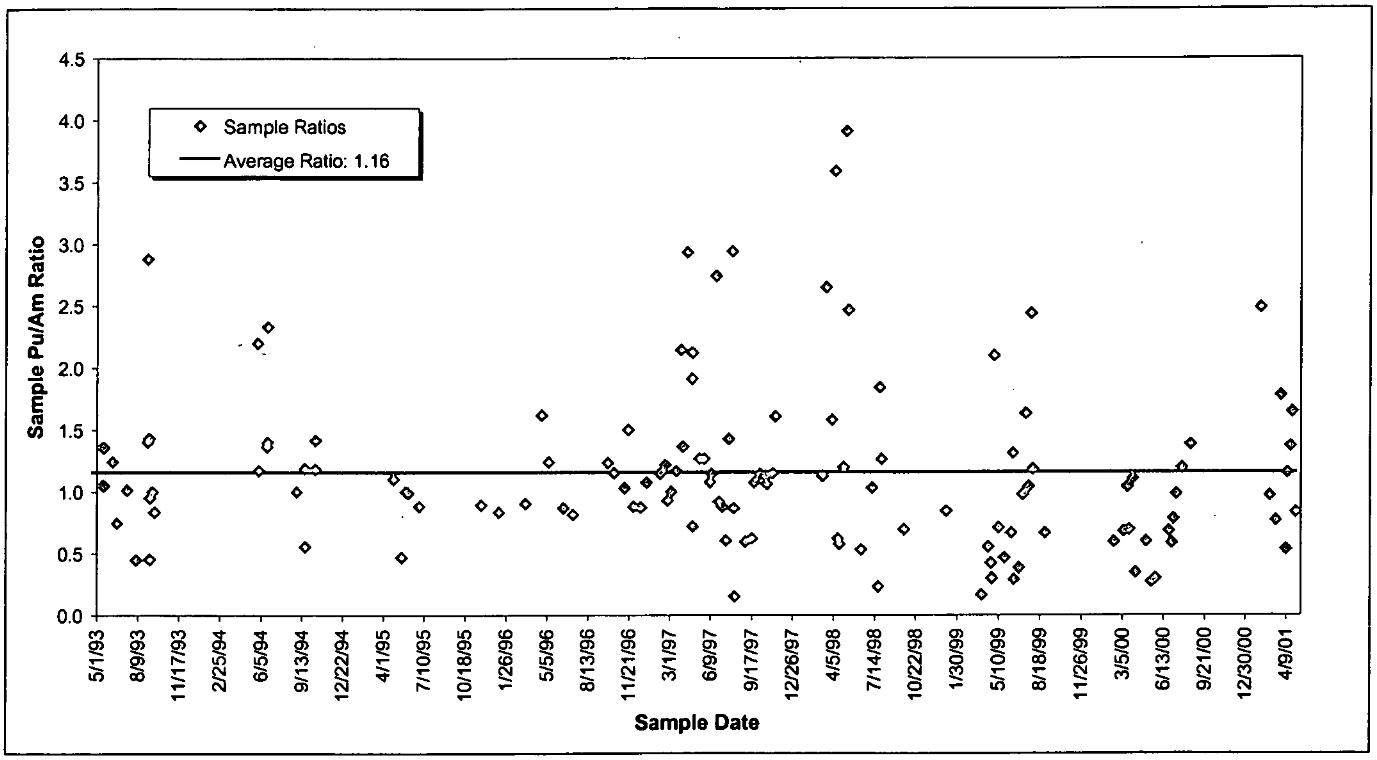
Figure 4-9. Relative Americium Load Contributions from Locations Tributary to GS10: 10/1/99 through 5/4/01.

33

4.2.3 Pu/Am Activity Ratio Evaluation

The ratios of sample Pu activity to Am activity (Pu/Am ratios) for surface-water samples collected within the GS10 drainage area are evaluated in this section. Figure 4-10 presents Pu/Am ratios for all surface-water samples collected at the current GS10 (4/6/93 – 5/4/01). Only samples with both Pu and Am results greater than or equal to 0.025 pCi/l are included in this evaluation to minimize the effects of analytical error near the detection limit.

Figure 4-10 suggests no long-term trend of increasing or decreasing Pu/Am ratios with time at GS10. Further analysis of data showed no strong seasonal, monthly, or annual trends in Pu/Am ratios. In short, the average Pu/Am ratio (1.16) at GS10 has been fairly constant for several years. Additionally, 44% of the samples displayed in Figure 4-10 had Am activities in excess of Pu activities.



Note: Ratios shown are for samples where both Pu and Am results were greater than or equal to 0.025 pCi/l.

Figure 4-10. Pu/Am Ratios for Surface-Water Samples at GS10

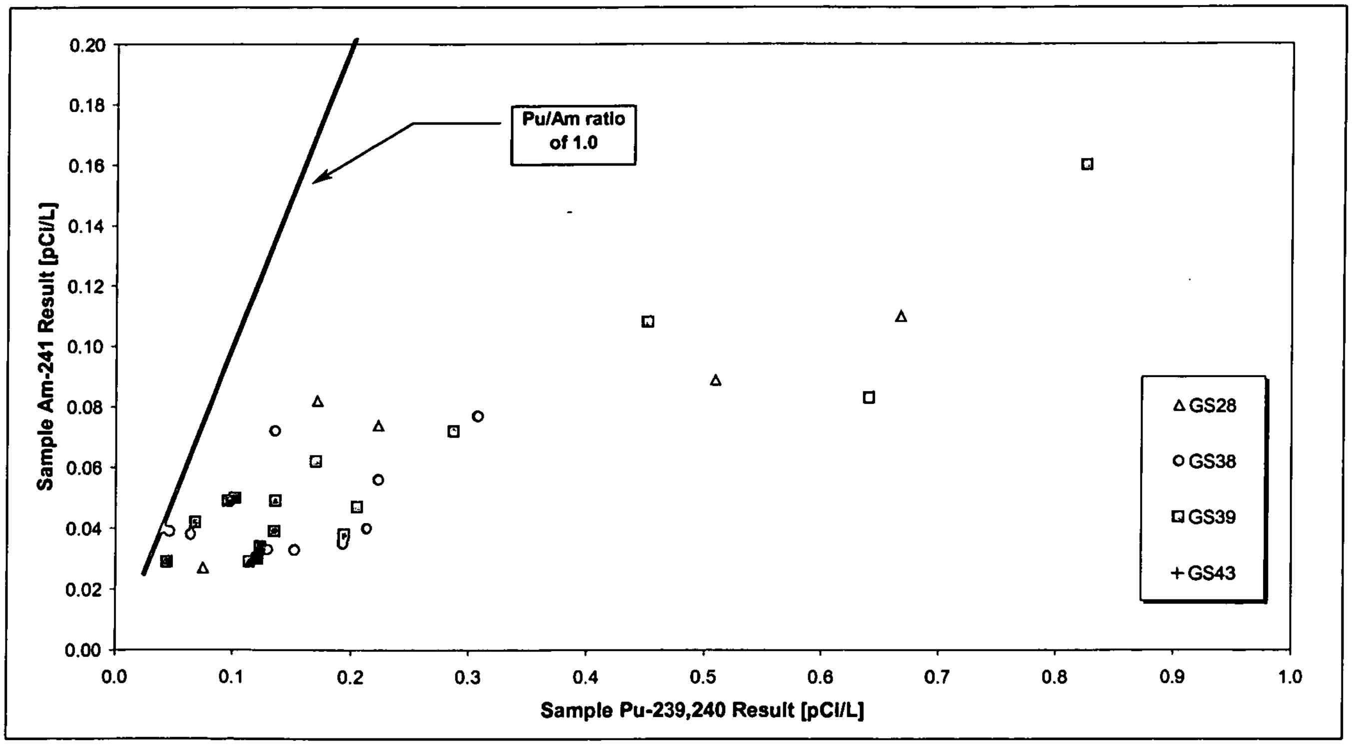
Table 4-5 summarizes average Pu/Am ratios for surface-water samples collected at automated monitoring locations within the GS10 drainage. Again, only samples with both Pu and Am results greater than or equal to 0.025 pCi/l were included to minimize the effects of analytical error near the detection limit.

Table 4-5 indicates that the average Pu/Am ratios from monitoring locations in the Central Ave. Ditch sub-drainage range from 3.54 to 4.30 (these locations are GS27, GS38, GS39, and SW022). The data from these locations are plotted in Figure 4-11 through Figure 4-13. These ratios are closer to the 'expected' range based on the material that has historically been used in Site operations. However, average Pu/Am ratios from monitoring locations in the main S. Walnut Cr. reach (GS10, GS40) and near the Solar Ponds (GS50) range from 0.63 to 1.16 (plotted in Figure 4-14 and Figure 4-15). Further, Figure 4-16 displays the ratios for all surface-water sampling locations within the GS10 drainage. This information further supports the hypothesis of a source 'enriched' in Am in the main S. Walnut Cr. stream reach.

Table 4-5. Summary Statistics for Surface-Water Pu/Am Activity Ratios for Automated Monitoring Locations Tributary in the GS10 Drainage.

Drainage/ Location	Average Pu/Am Ratio[1]	# Samples in Calculation
GS10	1.16	130
GS27	4.14	56
GS28	3.54	8
GS38	3.56	9
GS39	3.64	16
GS40	0.63	13
GS43	NA[2]	NA
GS50	1.09	1
SW022	4.30	31

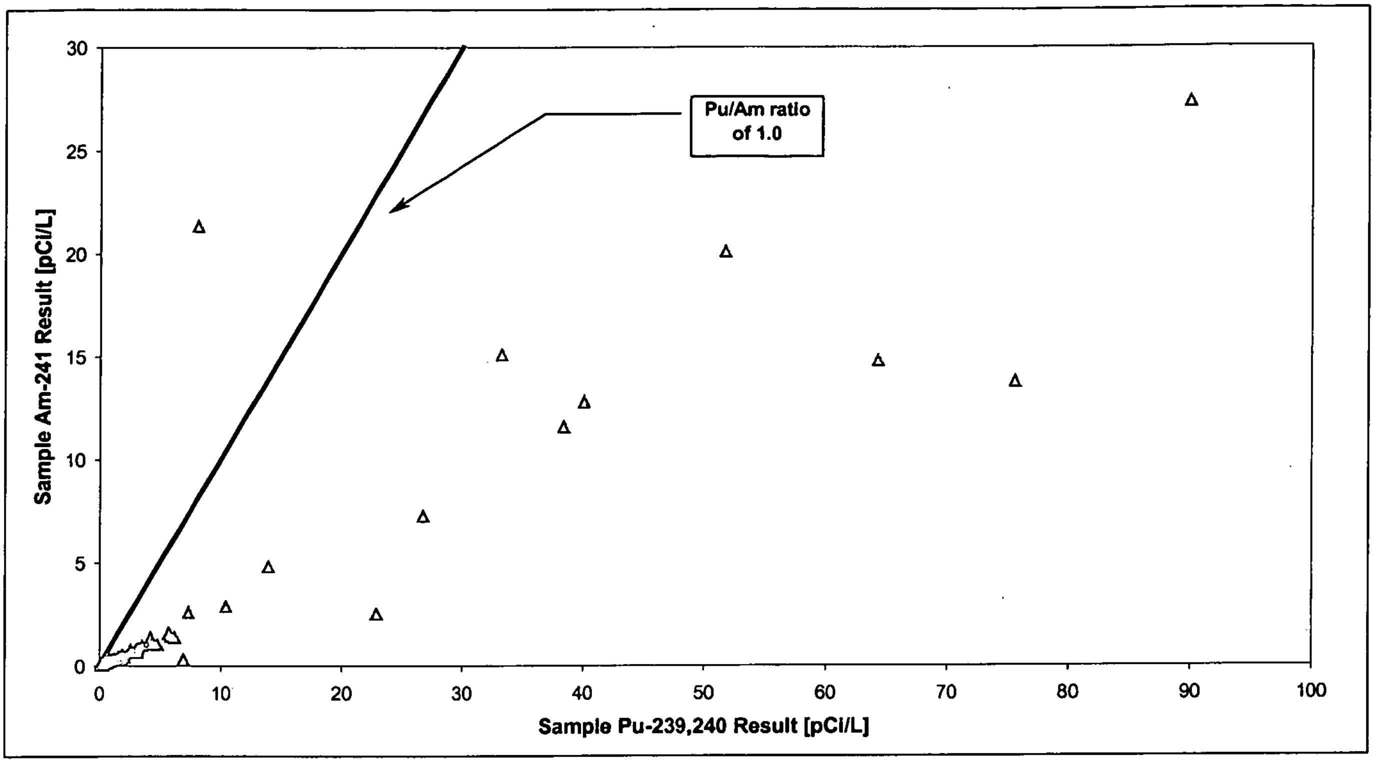
Notes: [1]Ratios shown are for samples where both Pu and Am results were greater than or equal to 0.025 pCi/l.
[2]No results from were greater than or equal to 0.025 pCi/l for calculation of reliable ratios.
GS28 was discontinued on 8/26/97, but is included here for reference.



Note: Includes all samples where both Pu and Am results are ≥ 0.025 pCi/l. No samples with Pu and Am ≥ 0.025 pCi/l at GS43.

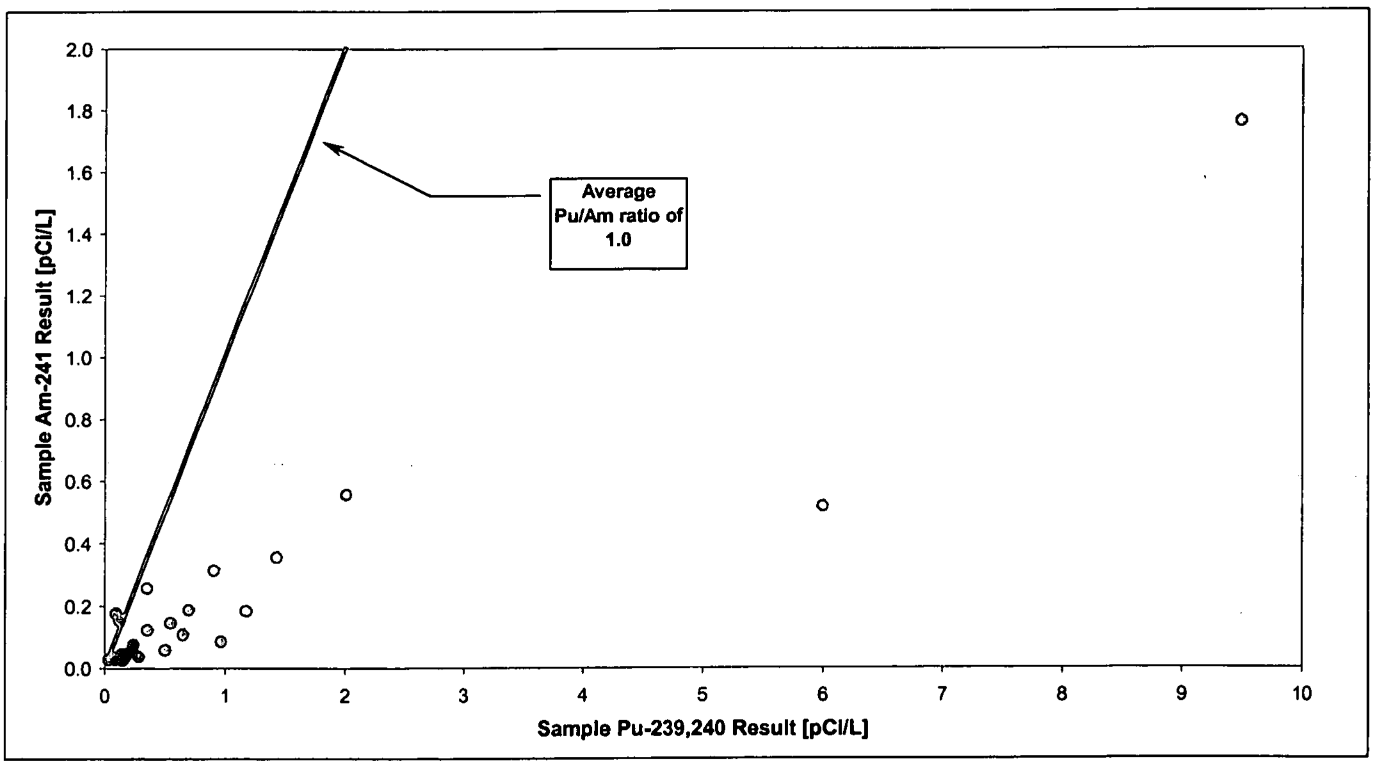
Figure 4-11. Variation of Sample Am-241 with Pu-239,240 Activity at GS28, GS38, GS39, and GS43.

30



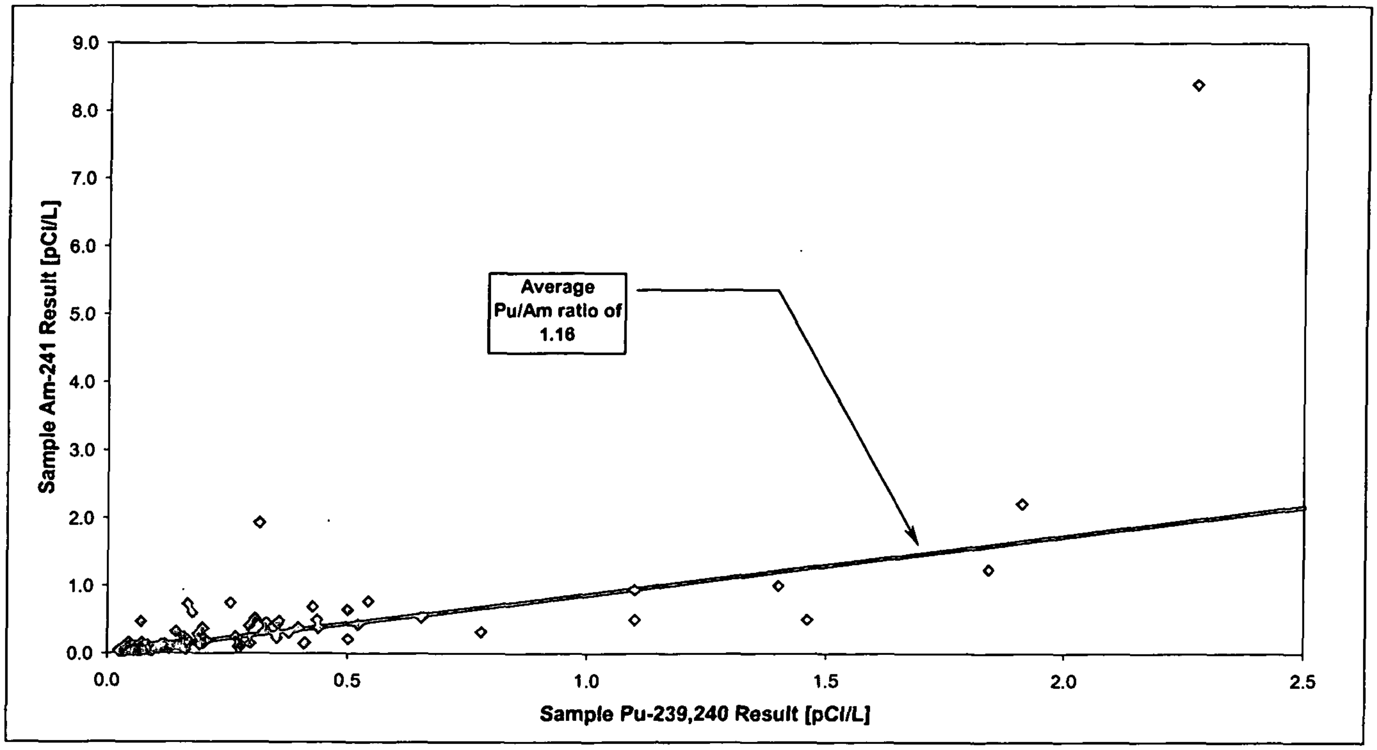
Note: Includes all samples where both Pu and Am results are ≥ 0.025 pCi/l.

Figure 4-12. Variation of Sample Am-241 with Pu-239,240 Activity at GS27.



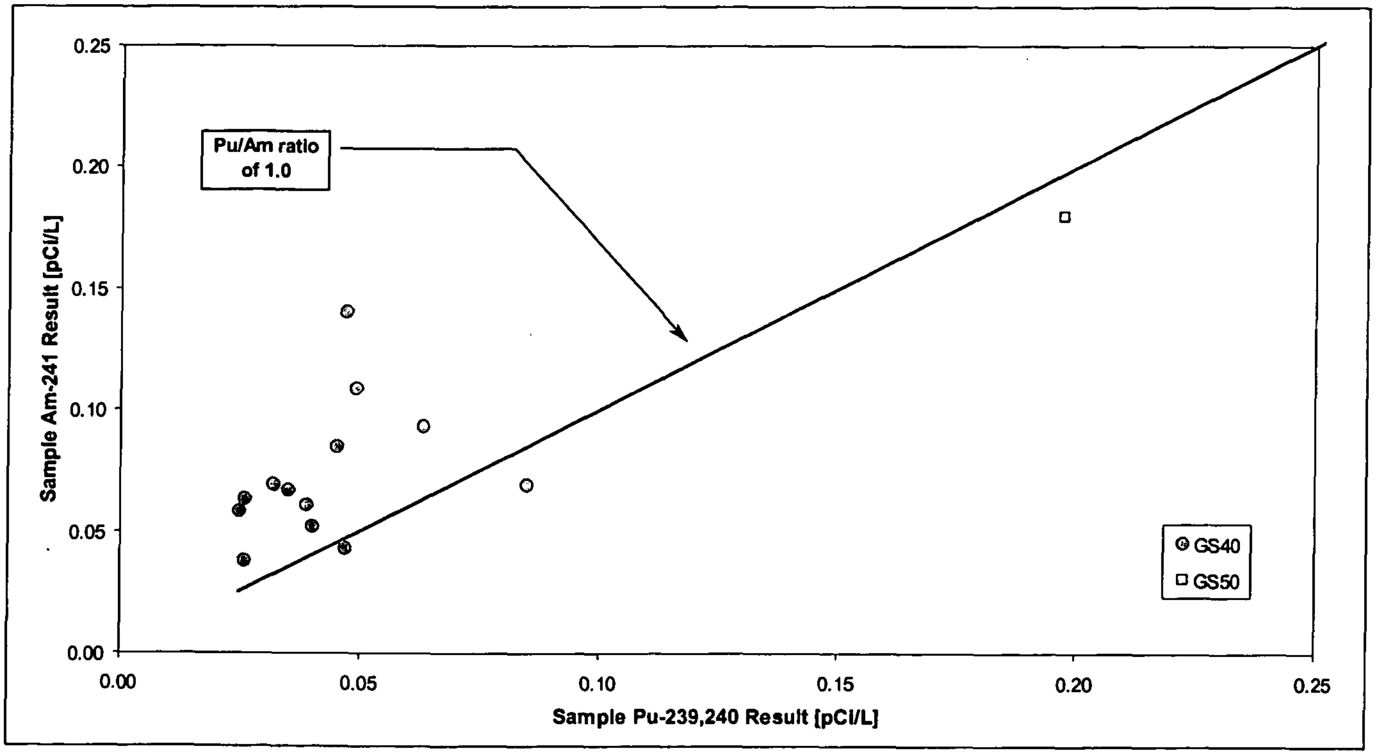
Note: Includes all samples where both Pu and Am results are ≥ 0.025 pCi/l.

Figure 4-13. Variation of Sample Am-241 with Pu-239,240 Activity at SW022.



Note: Includes all samples where both Pu and Am results are ≥ 0.025 pCi/l.

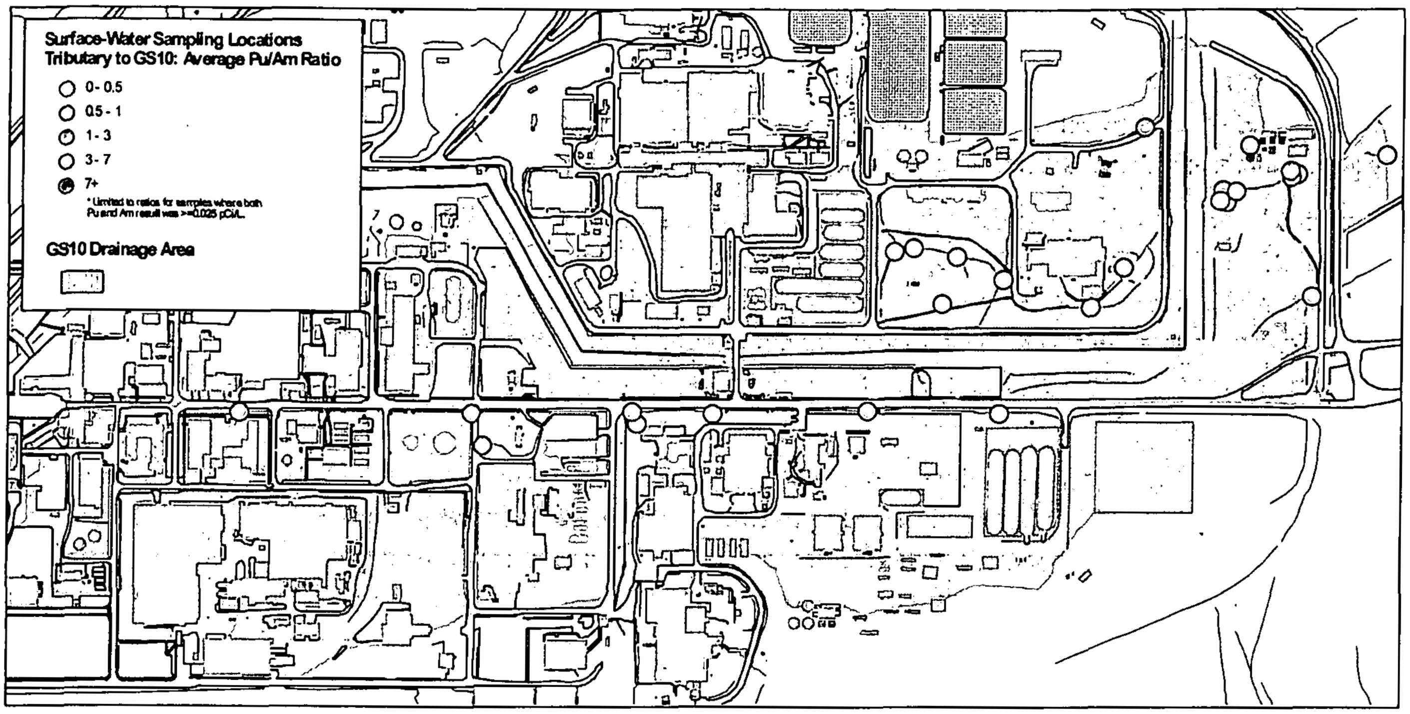
Figure 4-14. Variation of Sample Am-241 with Pu-239,240 Activity at GS10.



Note: Includes all samples where both Pu and Am results are ≥ 0.025 pCi/l.

Figure 4-15. Variation of Sample Am-241 with Pu-239,240 Activity at GS40 and GS50.

37



Note: Location averages include all samples where both Pu and Am results are ≥ 0.025 pCi/l.

Figure 4-16. Map Showing Average Pu/Am Ratios for Surface-Water Sampling Locations Tributary to GS10.

4.2.4 Water-Quality Correlations

As detailed in the *Sampling and Analysis Plan for Automated Synoptic Surface-Water and Sediment Sampling for the GS10 Source Investigation* (RMRS, 2000), an expanded analyte suite was applied to samples collected at GS10 during WY2000.[23] In addition to the normal RFCA analytes[24], samples were analyzed for CLP metals, chloride, fluoride, sulfate, TDS (total dissolved solids), and TOC (total organic carbon). The intent of these analyses was to allow for the use of statistical inference[25] to identify data patterns that may provide information about the location and/or characteristics of actinide source(s) tributary to GS10.

---

[23] Historic data (collected prior to RFCA) were also used where appropriate; the included data is noted in text, footnotes, and figure notes for each evaluation. Due to past programmatic changes, available analytical results for individual samples varied.

[24] RFCA analytes at GS10 include total Pu, Am, U-233/234, U-235, U-238, Be and Cr. Dissolved analyses are performed for Cd and Ag. Hardness is analyzed to facilitate metals evaluation. TSS is also analyzed when sample hold time requirements (< 7 days) are met.

[25] Statistical inference is the process of using information contained in the observed sample to draw conclusions about the population/process from which the sample was taken. Inferences are made regarding the parameters of the population. This process includes, but is not limited to, the use of parametric and non-parametric statistics, ranking, comparative visual assessment (plotting), spatial GIS assessment, etc.

AME research indicates that Pu and Am form strong associations with particulate matter.[26] During higher intensity precipitation events with increased raindrop impact, greater quantities of solids are transported in overland flow. Similarly, higher flow rates in ditches and creeks generally result in increased TSS values due to higher flow velocity and turbulence which causes sediment re-suspension. If contaminated particles are transported in surface water, then the observed actinide levels can be correlated with the amount of TSS.

Assuming that surface-soil and sediment actinide concentrations are evenly distributed in a drainage area, it is reasonable to expect that a relationship would exist between TSS and actinide concentrations (transported attached to soil particles) for surface-water samples collected from runoff at the drainage-basin outfall. However, if actinide source areas are more localized, then sample activities might not correlate well with TSS depending on the origin of the sampled runoff. This would be especially true for larger drainage areas with higher spatial precipitation variability.

Figure 4-17 shows a correlation between Pu activity and TSS in surface-water samples at GS10. This suggests that the Pu activity of the TSS is fairly uniform regardless of the origin of the suspended material. The median Pu activity of the TSS at GS10 is 0.98 pCi/g (maximum of 3.89 pCi/g) with 75% of the results between 0.49 and 2.35 pCi/g.[27] This may suggest a fairly uniform distribution of Pu in the drainage and /or localized source(s) with similar Pu activities (pCi/g).

However, Figure 4-18 shows a weaker correlation between Am activity and TSS in surface-water samples collected at GS10. This suggests that the Am activity of the TSS at GS10 varies more than for Pu depending the origin of the suspended material. The median Am activity of the TSS at GS10 is 0.92 pCi/g (maximum of 11.27 pCi/g) with 75% of the results between 0.43 and 3.672 pCi/g.[28] The histogram in Figure 4-19 also shows that the Am activity of the TSS is more variable than the Pu activity of the TSS. This may suggest a more variable distribution of Am in the drainage and/or localized source(s) relatively 'enriched' in Am.

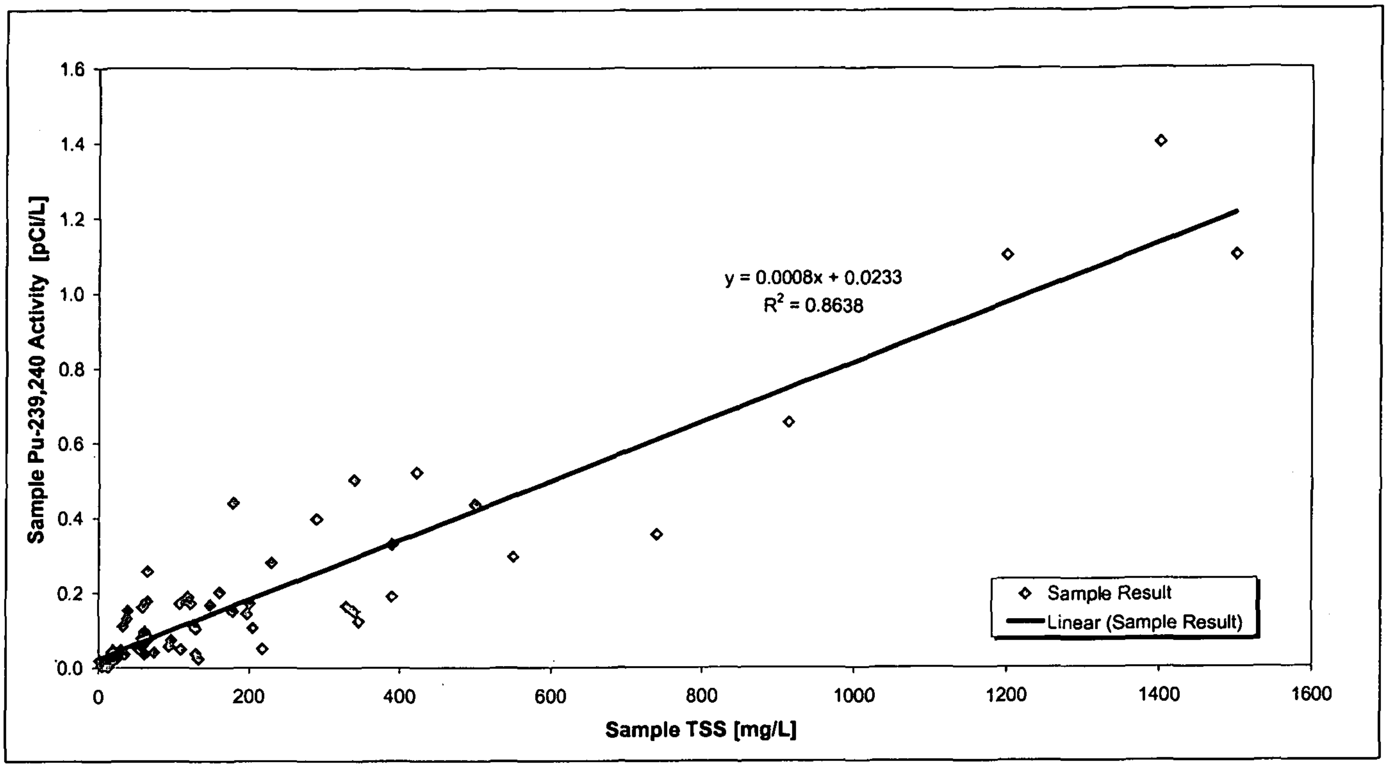
---

[26] The majority of Pu and Am transport is associated with particulate matter. Recent AME results provide additional confidence in this conclusion (Santchi 2000).

[27] Data near detection limits were not included in the calculation of the summary statistics. TSS results less than 5 mg/l and Pu results less than 0.025 pCi/l were excluded.

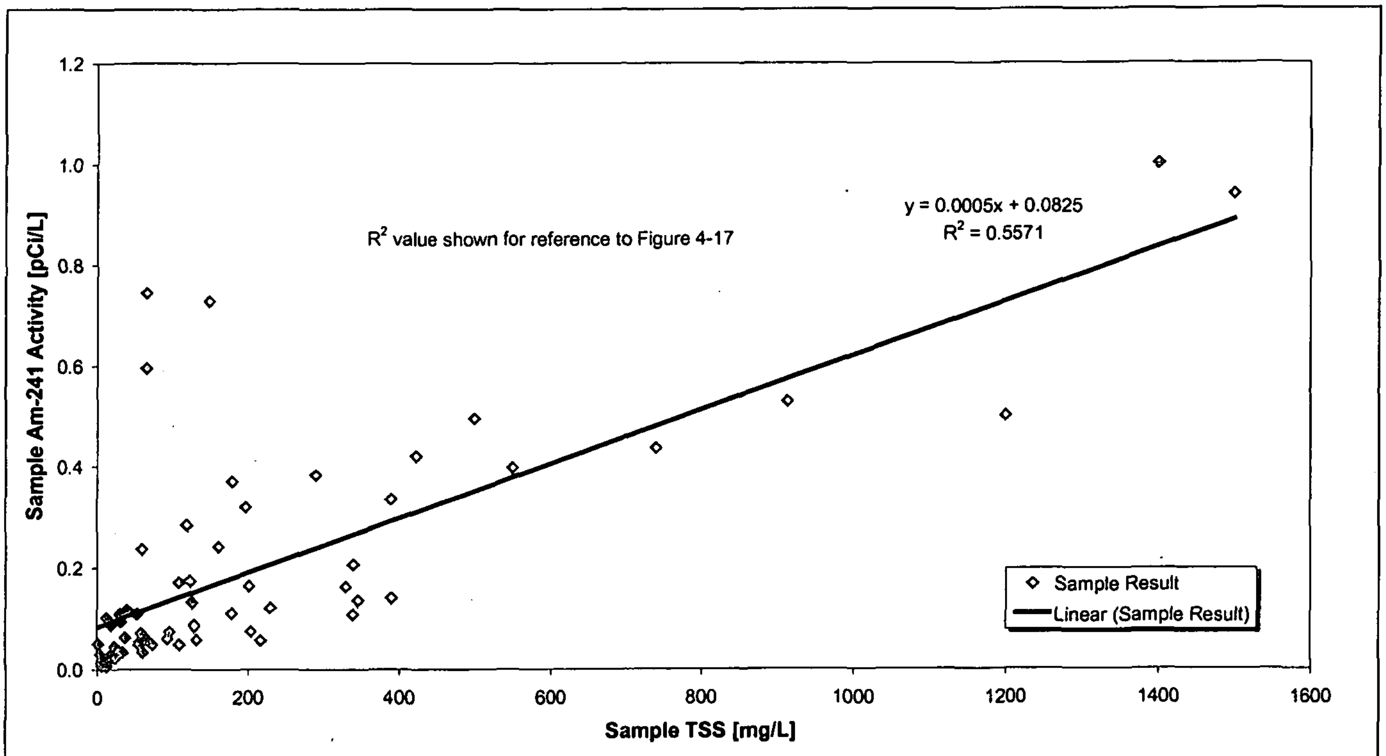
[28] Data near detection limits were not included in the calculation of the summary statistics. TSS results less than 5 mg/l and Am results less than 0.025 pCi/l were excluded.

39



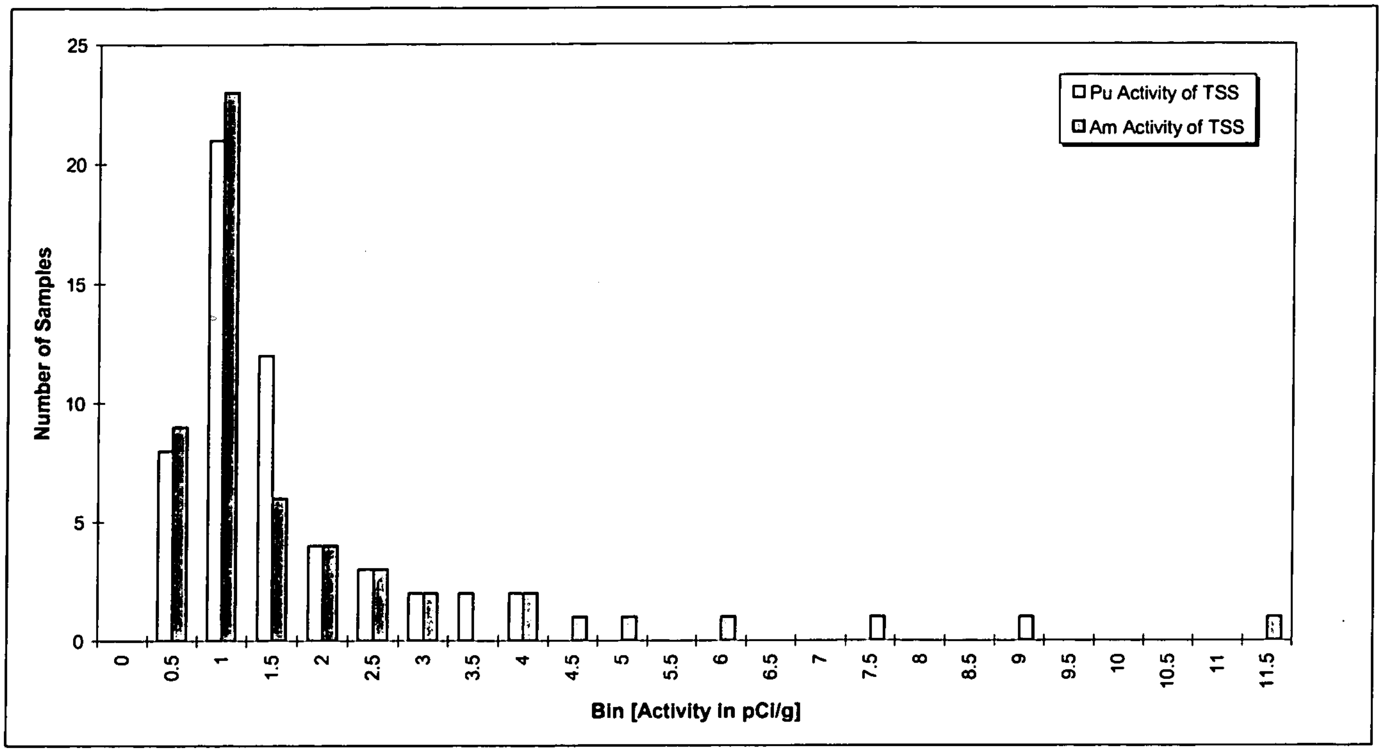
Note: No TSS results for samples that did not meet hold time requirements. Includes samples collected at GS10 from 4/6/93 through 5/4/01.

Figure 4-17. Variation of Pu-239, 240 Activity with TSS for Samples Collected at GS10.



Note: No TSS results for samples that did not meet hold time requirements. Includes samples collected at GS10 from 4/6/93 through 5/4/01.

Figure 4-18. Variation of Am-241 Activity with TSS for Samples Collected at GS10.



Note: Only samples above detection limits are included (TSS > 5 mg/l; actinides >= 0.025 pCi/l). Includes samples collected at GS10 from 4/6/93 through 5/4/01.

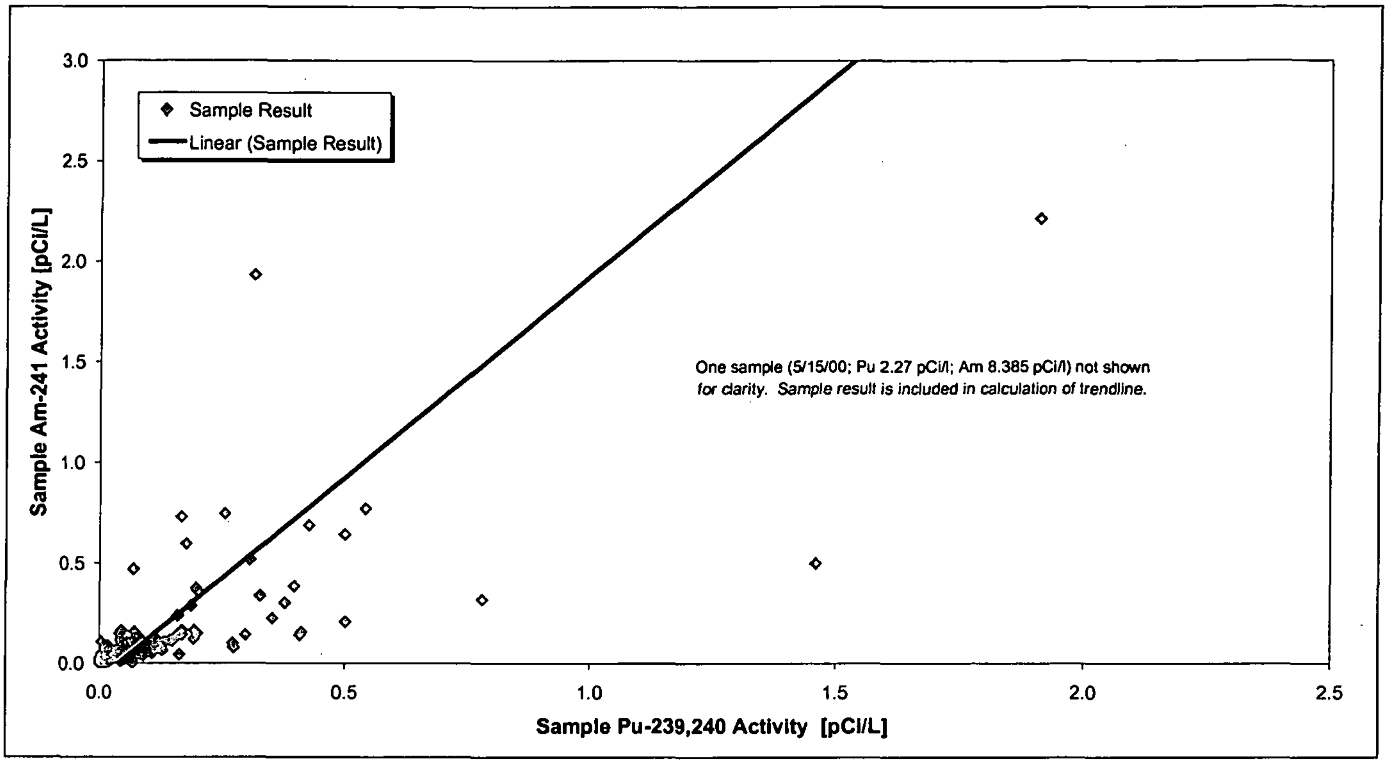
Figure 4-19. Histogram Showing Distribution of TSS Activities for Samples Collected at GS10.

Many of the automated surface-water monitoring locations show a good correlation between sample Pu and Am activities (Section 4.2). This relationship would be expected for drainage areas where the actinide contamination shows little Pu/Am ratio variability, or for small drainage areas where precipitation would not vary significantly. Samples collected at gaging station GS10 have routinely shown higher Pu/Am variability than for other automated monitoring locations, with many GS10 sample results showing Am activities significantly higher than Pu activities (see Section 4.2).[29] Figure 4-20 shows significant Pu/Am variability for samples collected during RFCA monitoring. This variability could be caused by the following:

- A source area(s) 'enriched' in Am that occasionally contributes actinides to GS10 when runoff originates from this area, based on spatial precipitation patterns;
- An intermittent source (e.g. a variably eroding area or streambed) 'enriched' in Am that contributes actinides to GS10 when hydrologic conditions are favorable; and/or
- A source area(s) 'enriched' in Am that continually contributes actinides to GS10 but is 'masked' by occasional contributions from areas with "expected" Pu/Am ratios depending on hydrologic conditions.

[29] The median Pu/Am ratio for Site surface soils is approximately 4.6. Surface-soil and sediment data is evaluated in greater detail in Section 4.4.

41



Note: Only continuous flow-paced sample results shown. Includes samples collected at GS10 from 10/1/96 through 5/4/01.

Figure 4-20. Relationship Between Pu-239, 240 and Am-241 Activities for RFCA Samples Collected at GS10.

Extensive evaluation of the following sample information was done to look for trends that might reveal source terms:

- Analytical results for Pu, Am, U isotopes, CLP metals (total), dissolved Cd, dissolved Ag, TSS, chloride, fluoride, sulfate, TDS, hardness, and TOC;
- Calculated Pu/Am ratios for all samples and Pu/Am ratios for samples where both Pu and Am were ≥ 0.025 pCi/l;
- Calculated activity of the TSS (both Pu and Am);
- Temporal sample information including collection date, month, season, and year;
- Sample collection methods including grab, storm-event, and continuous flow-paced;

- Sample period precipitation information including total depth, average intensity, and peak intensity[30]; and,
- Sample period hydrologic parameters including average and peak flow rate[31].

After using statistical inference to evaluate the data using numerous parameter pairings, data subsets, and time-periods, a subset of the RFCA samples collected at GS10 was discovered to have characteristics differing from the remaining samples. Table 4-6 lists these samples. For the remainder of this report, these samples will be referred to as the '*higher Am set*' because Am activity is generally high given the Pu activity. The remaining samples are referred to as the '*lower Am set*'.

Figure 4-21 and Figure 4-22 both show that the *higher Am set* has higher TSS activity (pCi/g Am) and higher Am relative to Pu activities (lower Pu/Am ratios). As with actinides, selected metals also show good correlation with TSS.[32] For these metals, the Am results associated with the *higher Am set* did not correlate as well with the metals as the Am results associated with the *lower Am set* (plots not shown for brevity). The Pu results associated with the *higher Am set* also do not share the same correlation with metals as the Pu results associated with the *lower Am set* (plots not shown for brevity). However, the Pu results are not as elevated above the expected fit as the Am values are. This is also indicated by comparing Figure 4-22 to Figure 4-23, which show that the Pu activities for the *higher Am set* are not as elevated as the corresponding Am activities when plotted against TSS. This suggests that if an Am 'enriched' source exists in the GS10 drainage, it also includes marginally higher Pu activities than the distributed source(s).

The evaluation did not indicate that the samples with higher Am also had any higher metals concentrations. In other words, if an Am source exists in the GS10 drainage, the data do not indicate that any of the analyzed metals are associated with that source in excess of the concentrations observed in the rest of the drainage. Similarly, Pu did not correlate with any of the metals other than expected metals associated with TSS. Also, water-quality parameter correlations provided no insight to the location of actinide source areas.

---

[30] Precipitation parameters were calculated for RFCA samples only. Data from six precipitation gages was extracted for each sample period. Grid-based precipitation values were then calculated using the inverse distance squared method. The grid values within the GS10 drainage (or other selected drainage area) were then arithmetically averaged to calculate parameters for each sample period (the maximum grid cell was also noted). Spatial precipitation parameters were also calculated for the automated synoptic sampling subdrainages and five other selected GS10 sub-drainage areas (based on hydrologic connectivity) to further evaluate spatial trends. The precipitation parameters (as an indication of runoff origin) were compared with analytical results in an attempt to assess spatial trends.

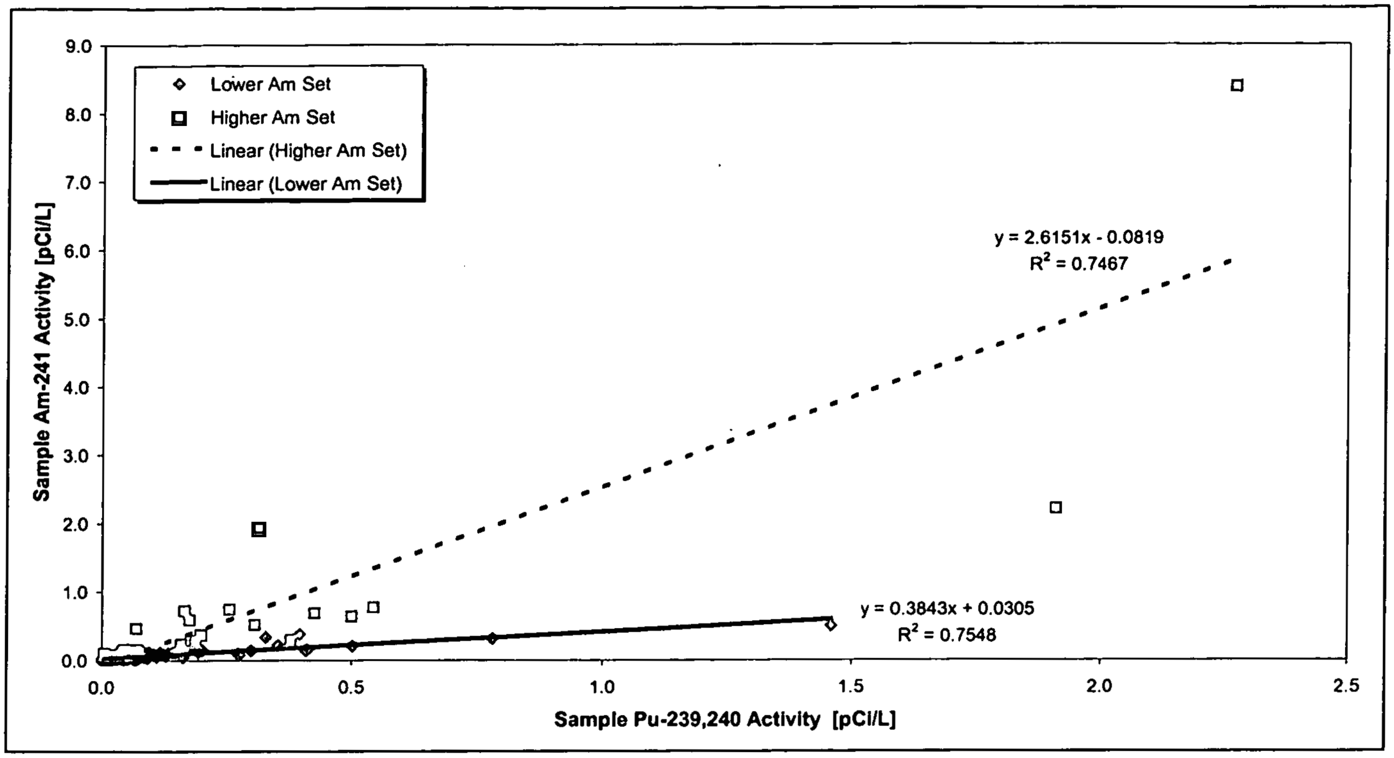
[31] The average sample-period flow rate was calculated by arithmetically averaging the instantaneous flow rates during each grab sample (uniformly 200ml or 1L). The peak flow rate for continuous flow-paced composites is simply the highest 15-minute interval flow rate during the sample period. The peak flow rate for storm-event samples is the peak 15-minute interval flow rate for the sampled precipitation event.

[32] At GS10 these metals are Al, Ba, Be, Cr, Co, Cu, Fe, Pb, Mn, Ni, K, V, and Z. These metals increase with increasing TSS concentration.

Table 4-6. Higher Am Set of RFCA Samples Collected at GS10.

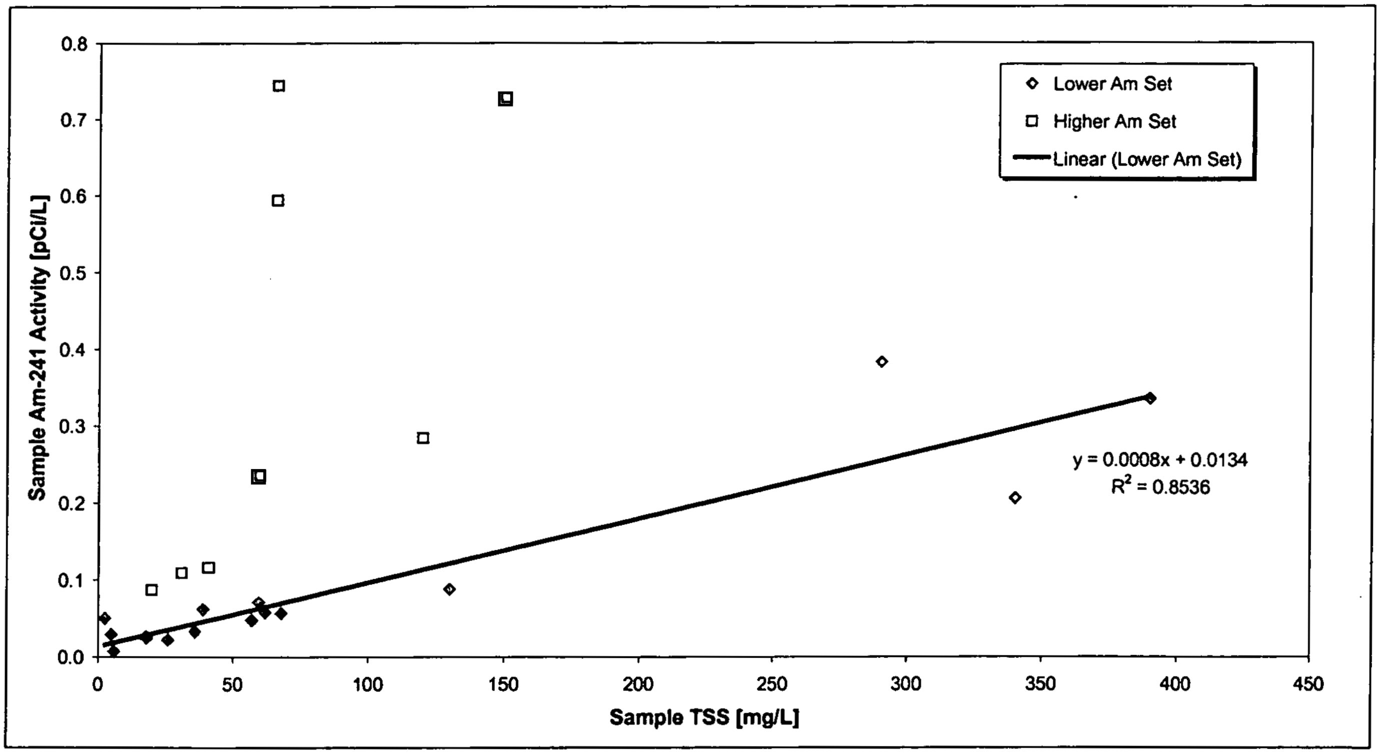
		Analytical Result		
Sample Number	Sample Date	Pu-239,240 [pCi/l]	Am-241 [pCi/l]	TSS [mg/l]
SW11083RM	05/12/1997	0.380	0.300	NA
97A2341-005	08/04/1997	1.910	2.210	NA
97A2515-002	08/06/1997	0.070	0.468	NA
SW11173RM	09/18/1997	0.427	0.687	NA
98D5103-002	06/11/1998	0.046	0.087	20.0
98D5239-003	07/23/1998	0.167	0.728	150.0
99D6175-006	03/15/1999	0.005	0.107	NA
99D6807-003	03/30/1999	0.316	1.930	NA
99D6890-003	04/15/1999	0.201	0.362	NA
99D6890-010	04/22/1999	0.046	0.109	31.0
99D7102-008	04/24/1999	0.177	0.594	66.0
99D7748-007	05/10/1999	0.543	0.768	NA
99D8061-001	05/24/1999	0.073	0.157	NA
99D8061-005	06/10/1999	0.189	0.284	120.0
99D8266-002	06/14/1999	0.152	0.116	41.0
99D8358-002	06/17/1999	0.047	0.163	NA
99D8806-001	06/29/1999	0.044	0.115	NA
00D1247-006	04/06/2000	0.257	0.744	66.0
00D1273-001	05/02/2000	0.308	0.517	NA
00D1304-001	05/15/2000	2.270	8.385	NA
00D1333-001	05/25/2000	0.043	0.145	NA
00D1350-002	06/19/2000	0.019	0.087	NA
00D1350-011	06/26/2000	0.161	0.236	60.0
00D1377-009	07/07/2000	0.500	0.640	NA
01D0692-005	04/09/2001	0.199	0.374	NA

44



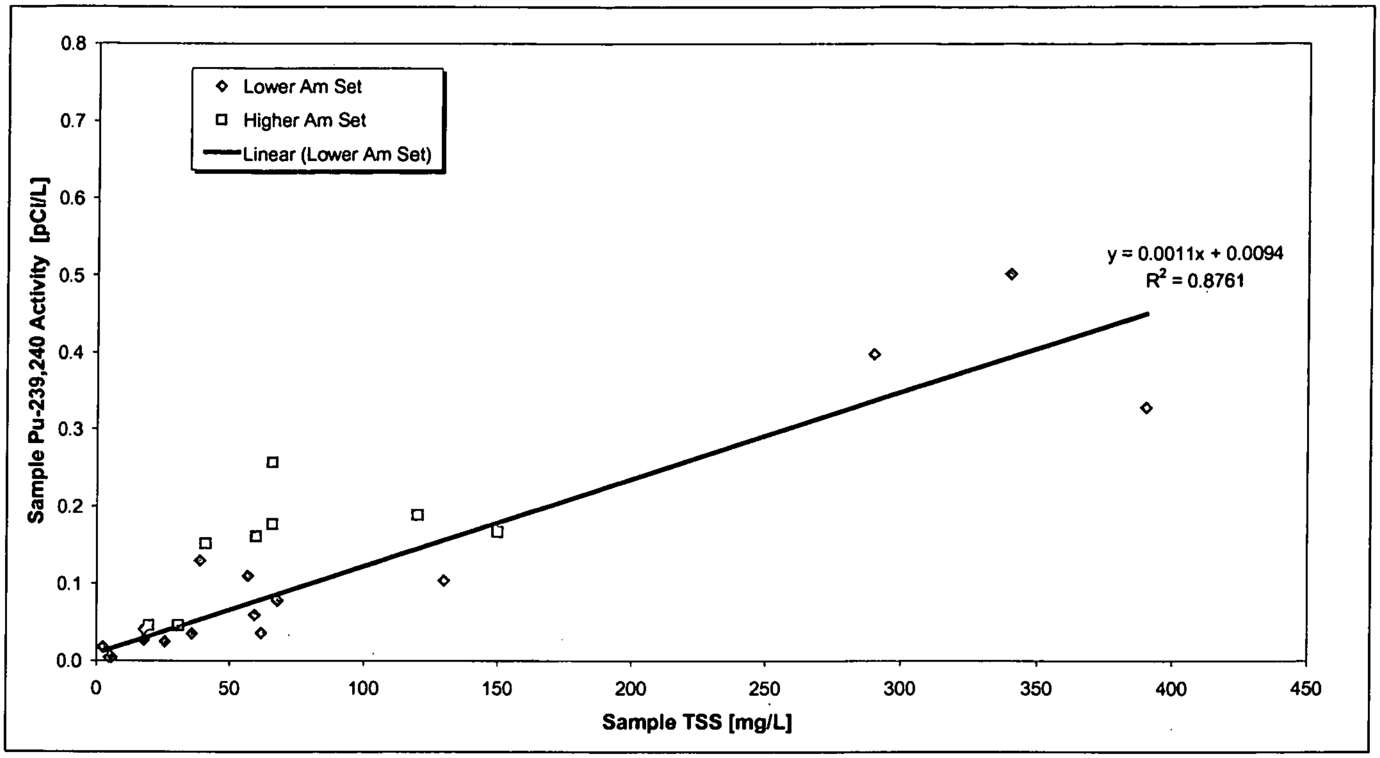
Note: Only continuous flow-paced sample results shown.

Figure 4-21. Variation of Am-241 with Pu-239, 240 Activities for RFCA Samples Collected at GS10.



Note: Only continuous flow-paced sample results shown with results for both Am and TSS.

Figure 4-22. Variation of Am-241 Activity with TSS for RFCA Samples Collected at GS10.



Note: Only continuous flow-paced sample results shown with results for both Pu and TSS.

Figure 4-23. Variation of Pu-239, 240 Activity with TSS for RFCA Samples Collected at GS10.

As expected, GS10 data indicate that TSS increases with both increasing peak flow and increasing peak precipitation intensity (Figure 4-24 and Figure 4-25). For more intense runoff events (as indicated by peak flow and peak precipitation intensity), the increased energy associated with higher raindrop impact and flow velocities would mobilize higher amounts of soils and sediments. Assuming that the actinide contamination is fairly evenly distributed throughout the drainage, then it would be expected that the measured activity (actinides associated with the TSS) would also correlate with peak flow and precipitation intensity.

Figure 4-26 and Figure 4-27 show that the samples in the *higher Am set* tend to be associated with both lower peak flows and lower peak precipitation intensities. These characteristics could be caused by the following:

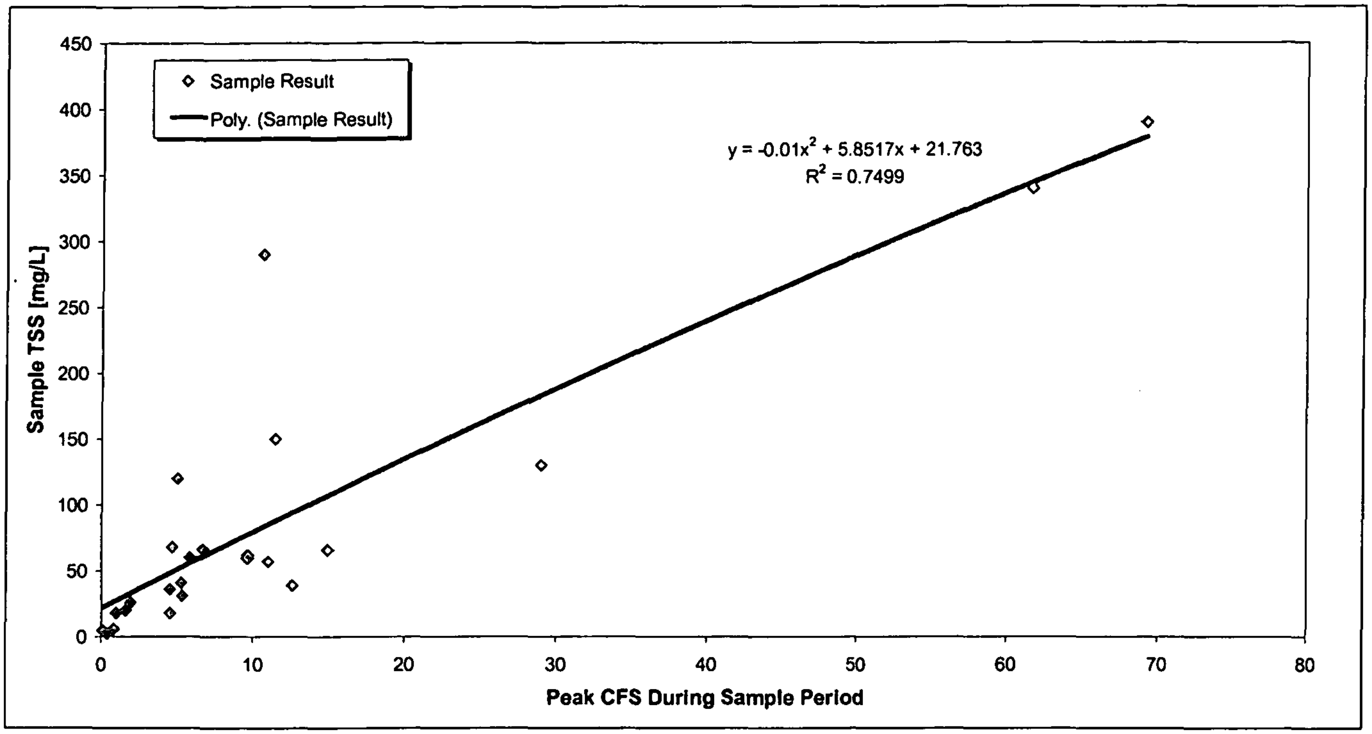
- A relatively impervious source area(s) 'enriched' in Am could be located fairly close to GS10. Therefore, for smaller precipitation events, local runoff reaches GS10 with fairly high Am activity (pCi/l), but during larger events this activity is diluted by relatively cleaner runoff from less contaminated areas located further upstream.

- A source(s) 'enriched' in Am could be incorporated within the sediments in the main S. Walnut Cr. reach between the 750 Pad and GS10. For certain hydrologic conditions (lower intensity precipitation) the majority of the runoff would originate from impervious areas such as buildings and roads. A smaller proportion of the runoff would originate as overland flow from more pervious areas with 'normal' surface-soil Pu/Am ratios due to the lack of excess rainfall. These flows from impervious areas could then cause resuspension of sediments and stream bank erosion from the main S. Walnut Cr. reach as the flows concentrate, especially downstream near GS10. This mechanism could result in the collection of surface-water samples with low Pu/Am ratios. Conversely, higher intensity precipitation events could contribute overland flow from areas with more typical

46

surface-soil Pu/Am ratios, and the resulting surface-water Pu/Am ratios would be higher, depending on the relative contribution of actinides from the different source areas.

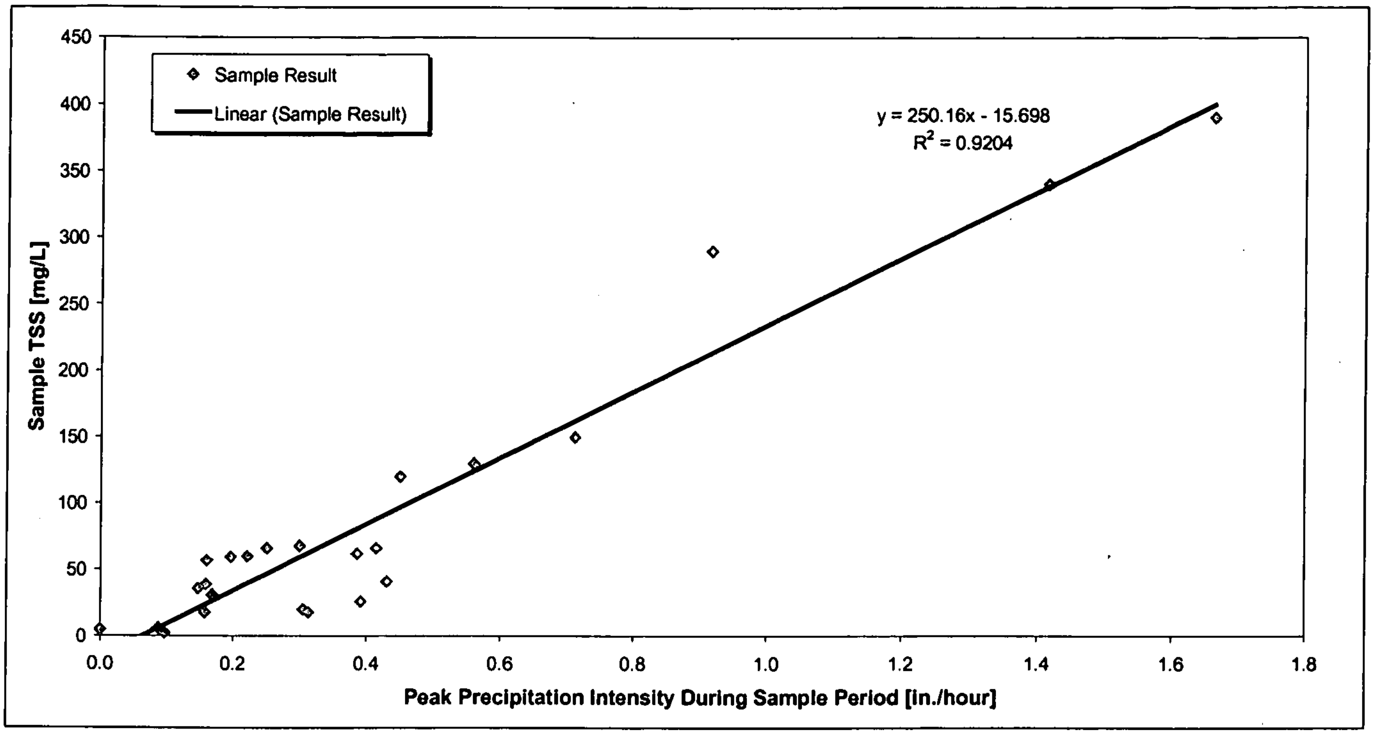
- A source(s) 'enriched' in Am is incorporated within the sediments in the main S. Walnut Cr. reach and could intermittently be contributing material to samples collected at GS10. During past years, intermittent/variable actinide loading to the creek and various construction projects could have resulted in 'pockets' of source material with low Pu/Am ratios. As sediment is resuspended and stream banks are eroded, the exposure of source terms could vary temporally, and the resulting sample variation could be a reflection of the heterogeneity of the actinides in the source material.



Note: Only continuous flow-paced sample results shown.

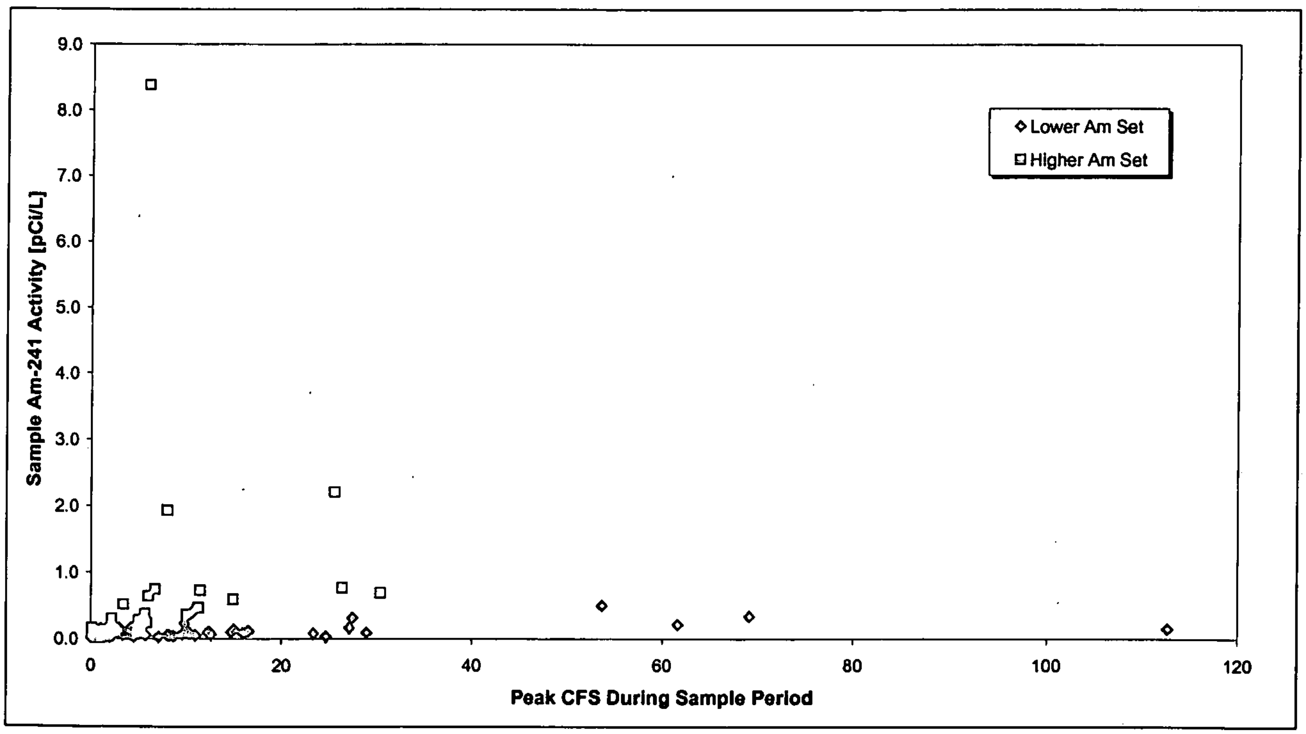
Figure 4-24. Variation of TSS with Peak Flow for RFCA Samples Collected at GS10.

47



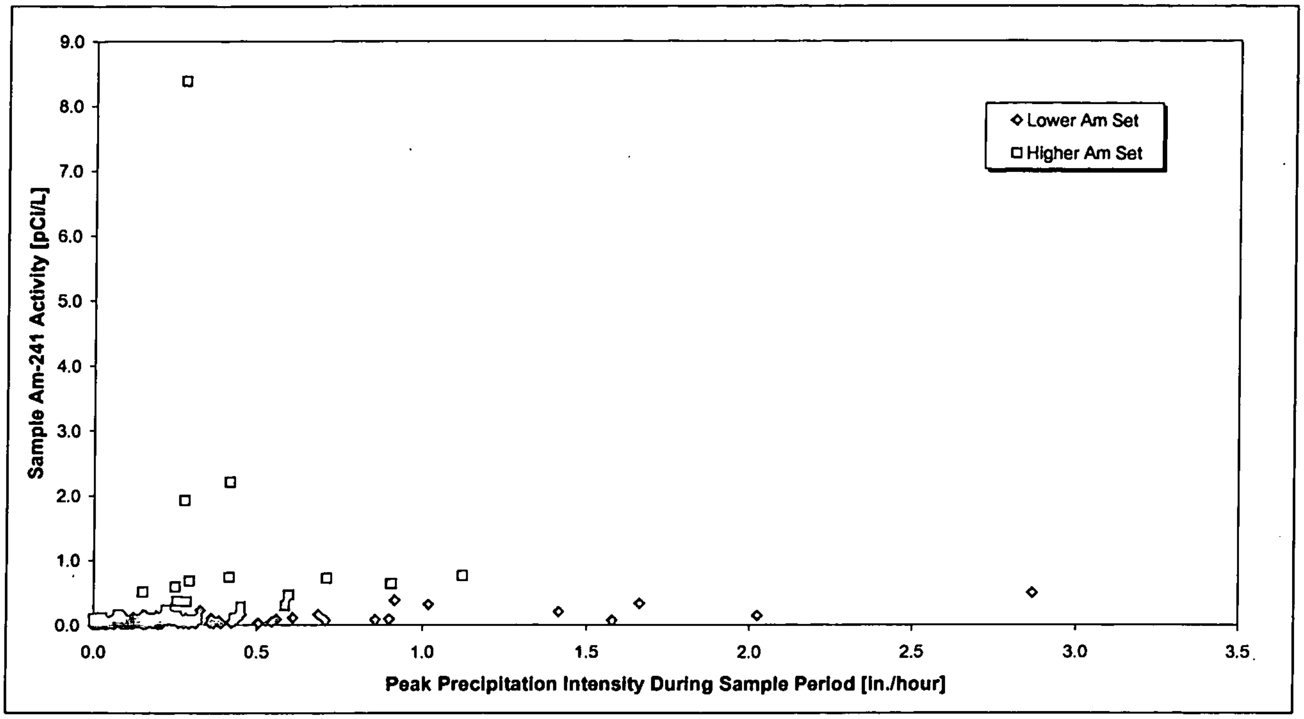
Note: Only continuous flow-paced sample results shown.

Figure 4-25. Variation of TSS with Peak Precipitation Intensity for RFCA Samples Collected at GS10.



Note: Only continuous flow-paced sample results shown.

Figure 4-26. Variation of Am-241 Activity with Peak Flow for RFCA Samples Collected at GS10.



Note: Only continuous flow-paced sample results shown.

Figure 4-27. Variation of Am-241 Activity with Peak Precipitation Intensity for RFCA Samples Collected at GS10.

The sediment data indicate that the S. Walnut Cr. stream reach contains legacy contamination with low Pu/Am ratios (Section 4.4), and supporting information can be found in the Historical Release Report (HRR).[33] According to the HRR, pond reconstruction activities took place upstream of Pond B-1 from 1971 to 1973. A subsequent sediment study by Colorado State University (CSU) indicated contamination of sediments in the B-Series drainage. The study also concluded that the reconstruction activities caused the inventory of Pu in B-1 to increase from 0.085 Ci in 1971 to 2.9 Ci in 1973 (activity varied from 10 to 502 pCi/g), suggesting the resuspension of contamination in the stream reach.

A 1973 study also found contamination "from the 'west culvert' (the culvert west of the Building 995 outfall) to the 'east culvert' (the culvert immediately east of the Building 995 outfall)." The area of contamination was estimated to cover an area approximately 650 feet in length with a estimated width of 6 feet. The HRR further states that " in the fall and winter of 1973, removal operations for contaminated soil were being conducted in the stream bed below the Building 995 outfall." Therefore, the possibility exists that legacy contamination in this area has been incorporated in to the sediments, and that these sediments may be intermittently contributing actinides to GS10.

---

[33] Generally, the HRR provides information regarding the general time and location of past releases to the environment. The HRR is less clear as to the exact constituent composition of those releases.

49

Although no reference is made in the HRR regarding the existence of Am in this reach, more recent monitoring data clearly show low Pu/Am ratios. If an Am 'enriched' source exists in the main S. Walnut Cr. reach, the question remains as to the origin of this material. The Historical Release Report (HRR) contains information suggesting several pathways discussed below.

- **Pathway 1**: Contaminated runoff from areas surrounding the Solar Ponds:

  The Solar Ponds were used primarily for the disposal of low-level radioactive wastes contaminated with high concentrations of nitrate. The Solar Ponds were also used for the disposal of other difficult to treat wastes. The Solar Ponds have historically received wastes from B774, which was placed into service in 1953. B774 was used for the treatment of high-level radioactive aqueous wastes, waste oils, and non-radioactive waste photographic solutions. The low-level radioactive waste solutions produced from the original process-waste collection system were transferred to the Solar Ponds and/or were treated.

  The majority of soil and sediment samples from the areas surrounding the Solar Ponds show Pu/Am ratios of less than 1.0 (see Section 4.4). If waste streams from the chemical recovery of Pu and Am were discharged to the Solar Ponds, then the Solar Ponds could be the source of the Am in this area. Contaminated salts from the Solar Ponds were often blown across the surrounding areas and numerous past construction projects might have unknowingly spread contamination.

  Runoff from this area flows to S. Walnut Cr. through a ditch along the PA perimeter road northeast of B991. Considering the topography of this area (low gradient) and the relatively pervious surfaces (unpaved dirt areas) it is unlikely that this area contributes runoff for most precipitation events. Although this area is likely not the current source of the actinides associated with the *lower Am set*, it may have been a past source of Am to S. Walnut Cr.

  Recently installed gaging station GS50 monitors runoff from the southern edge of the Solar Ponds area (Figure 4-1). GS50 became operational on 3/28/01 as a Performance Monitoring location in support of future Solar Ponds remediation activities. All of the runoff measured at GS50 is tributary to GS10, consequently GS50 also serves as a Source Location monitoring station for GS10. To date, only two samples have been analyzed from GS50. Both samples showed only moderate activities, but the average Pu/Am ratio is low (0.64), as expected for this location.

- **Pathway 2**: Direct discharges to S. Walnut Cr. through an outlet below B995 associated with the Original Process Waste Lines (OPWL):

  The OPWL are a network of tanks and underground pipelines constructed to transport and temporarily store aqueous chemical and radioactive process wastes from points of origin to on-site treatment and discharge points. Depending on the level of radioactivity and chemical composition, process wastes were routed to B774 for treatment, Pond B-2, or the Solar Evaporation Ponds. Most OPWL lines which were not converted to the new process waste system (completed in 1984) are believed to have been abandoned in place. The OPWL Closure Plan indicates that underground pipelines outside of buildings were abandoned in place without sealing or decontamination; however, other references indicate that most or all of the system was flushed, sealed, and left in place.

50

The OPWL line that discharged below B995 extends from just southeast of Solar Pond 207B, under the Perimeter Security Zone (PSZ), along the south side of the 995 complex, to the outfall. The HRR identifies the following releases from this outfall:

- Treated process waste from B774 from at least July 1953 until the early 1980s; these flows included decontamination laundry wastewater.
- Untreated process waste from B774 from at least July 1953 until January 1954; it is believed that this untreated water was primarily decontamination laundry wastewater.
- Untreated laundry wastewater from B771 from at least July 1953 until 1965; may have included waste from B771 analytical laboratory, radiography sinks, personnel decontamination room, and runoff.

Other unknown releases (accidental waste routing) from this pipeline may have reached S. Walnut Cr. during past Site operations. Table 4-7 lists events for the B-Series drainage that may be associated with this OPWL pipeline.

Table 4-7. Selected B-Series Drainage Ponds Operational Problems (from HRR).

Date	Concern	Cause
February 1965 – April 1965	High nitrate concentrations at Pond B-4	Unknown
November 1966	High Pond B-4 nitrate concentrations	Release of high nitrate liquid from B774
March 1972	High activity concentrations in Pond B-1, Pond B-2, Pond B-3, and Pond B-4	Inadvertent release of liquid from B774
January 1972 – December 1972	High Pu concentrations in effluent water at Pond B-4	Number of changes in waste handling, waste treatment, and drainage pond use as well as pond reconstruction activities

Numerous accidental releases of process waste occurred during the operating history of the OPWL. Table 4-8 lists selected known OPWL releases from the HRR. The HRR indicates that OPWL releases occurred as a result of the following:

- Leakage of tank and pipeline fittings, including tank/pipeline connections, pipeline joints, elbows and reducers, junction boxes, and valves;
- Pipeline breakage due to construction activities, soil settling, and building foundation settling;
- Overflows of tanks and pipeline junction boxes and valve vaults; and,
- Tank and pipeline corrosion and deterioration.

The contamination associated with these subsurface releases could persist in the soils for years. However, numerous construction activities in this area (construction of PSZ, utilities work, construction of B995 equalization basins and other improvements, etc.) could have inadvertently exposed and spread contamination.

51

This contamination could have moved to the sediments in S. Walnut Cr. in the past and/or still be available in surface soils for transport in overland runoff.

Table 4-8. Summary of Selected Known OPWL Releases (from HRR).

Date	Location	Description
4/75	East of B995	A leak was found in a process waste line leading to Pond B-2 just east of B995, where the line passed through a metal culvert under the outside perimeter fence road. The leak was detected by excess water in the culvert. The pipeline was apparently damaged by heavy earth moving equipment. The pipeline was repaired on 5/2/75 and returned to service on 5/5/75. Because contamination at the leak site was minimal, no soil removal was deemed necessary.
4/11/78	Near Solar Evaporation Pond 207B	A process waste line at Solar Evaporation Pond 207B was broken during excavation of the line.
7/85	East of Protected Area and west of B995	An abandoned process waste line was uncovered and broken during excavation for the sanitary sewer-system replacement project. Contamination was found and removed. Both ends of the broken pipe were removed.

- <u>Pathway 3</u>: Contaminated runoff from disintegrating pondcrete stored on the 750 Pad:

  In the late 1980s, pondcrete and saltcrete were stored on the 750 Pad at the upstream end of S. Walnut Cr. The pondcrete consisted of solidified low-level radioactive and hazardous waste extracted from the Solar Evaporation Ponds, while saltcrete consisted of solidified low-level radioactive and hazardous waste extracted from process waste at B374 by distillation. Several instances occurred where broken waste containers allowed decomposing pondcrete and saltcrete to spill onto the 750 Pad. The HRR contains specific references to spills from September 27, 1988 through July 24, 1989.

  The original 750 Pad configuration provided no protection from precipitation or containment of runoff water. These spills were exposed to precipitation with runoff flowing directly to S. Walnut Cr. Data collected at the time indicated that this water exceeded RFP water-quality guidelines. Although no information is presented in this report regarding the chemical composition of these waste sources, the information suggests that Am may have been present due to the origination of the material in the Solar Ponds.

- <u>Pathway 4</u>: Contaminated runoff from dispersed sanitary sludge south and east of B995:

  Sludge from the wastewater treatment plant (B995) is routinely placed in a series of gravel- and sand-lined beds until sufficiently de-watered for packaging and shipment for disposal. The configuration of the beds has changed several times since 1952 but they have been in regular operation. There have been many incidents of the sludge in the beds overflowing towards the East Perimeter Road. Because the beds were open to the atmosphere, sludge was noted to have become airborne and dispersed. In June 1973, air samples collected on the East Perimeter Road were unusually high after the area had been disturbed by construction equipment preparing the road for re-asphalting.

  Soil samples from the area (see Section 4.4) show moderate activities (average Pu 1.51 pCi/g; average Am 0.61 pCi/g). The average Pu/Am ratio for these locations is 2.7; slightly lower than normal for the Site. There are several locations with ratios less than one (1.0).

The WWTP has a long history of receiving various routine and accidental waste streams including process wastes and decontamination laundry wastewater. Existing references (HRR) indicate that the three original earthen Solar Ponds were used in series and that the effluent from these ponds was discharged to the WWTP. Although many of the releases to the WWTP are unknown, the HRR does include references to known releases (Table 4-9).

Table 4-9. Summary of Selected Known OPWL Releases to the WWTP (from HRR).

Date	Location	Description
6/65	East of "G" Road and north of "A" Road	High nitrate concentrations in sanitary sewer system waste was attributed to infiltration of nitrate from soil surrounding the sanitary sewer lines. The source of the nitrate was determined to be leaks and breaks in the process waste line which paralleled the sanitary system.[34]

Based on the above information, it is possible that sludge overflow from the WWTP has historically contributed actinides to S. Walnut Cr. However, the current water-quality impacts from this area are unknown.

- <u>Pathway 5</u>: Direct discharges to S. Walnut Cr. through an historic septic tank east of B991 (PAC 900-1311):

  Prior to construction and startup of the Site's wastewater treatment plant in 1953, sanitary wastewater was managed with a septic system approximately 200-300 yards east of Building 991. In various Site documents, this system was referred as the "temporary sewage disposal bed", "sewage test area", or the "wooden septic tank". The tank is believed to have discharged to S. Walnut Cr. through a wooden flume structure.

  According to the 1999 HRR update, the exact location and the nature of the liquids treated was poorly documented. Based on a review of 1952 waste disposal documents, the fluid flowing through the temporary sewage disposal bed was believed to be sewage. No additional documentation was identified which detailed the fate of constituents released to the environment. Documentation is also lacking that described the termination of usage or removal of the septic tank.

  Although the exact location is unclear, the probable location is immediately south of B995 in the S. Walnut Cr. streambed just upstream of the culvert under the perimeter road. In June 1999, sampling to support characterization of PAC 900-1311 for possible designation as NFA was conducted per the Agency approved Sampling and Analysis Plan for Characterization of Potential No Further Action Sites. A total of eight samples, 4 surface samples (0-4 inches in depth) and 4 borehole samples (7-24 inches in depth) were collected and analyzed for isotopic radionuclides. Radiological analytical results for the surface soils ranged in value from 0.334 to 1.63 pCi/g Am, and 0.219 to 0.879 pCi/g for Pu. Interestingly, analytical results for the subsurface soil (borehole) ranged in value from 0.228 to 7.02 pCi/g Am, and 0.929 to 8.34 pCi/g Pu. The Pu/Am ratios for all eight samples ranged from 0.41 to 9.3, with 7 of 8 being less than 2.6 Pu/Am. Although the available documentation and corresponding time period suggest that Pu and Am were not associated with this waste stream, the recent sampling is indicative of contamination in this area. The low Pu/Am ratios,

[34] Although the HRR discussion focuses on nitrate, it is reasonable to assume that other process waste constituents were also present.

coupled with the fact that the subsurface samples were generally of higher activity than the surface samples, support the hypothesis of an Am enriched source term that is incorporated into erodable sediments in S. Walnut Creek.

In summary, data suggest that a source term 'enriched' in Am may be associated with the sediments in the main S. Walnut Cr. stream reach. The HRR and soil/sediment data (see Section 4.4 for soil/sediment discussion) provide information supporting this hypothesis. However, sufficient data do not exist to establish the extent and exact location of this potential source term.

4.3 Synoptic Surface-Water Monitoring Data

As detailed in the *Sampling and Analysis Plan for Automated Synoptic Surface-Water and Sediment Sampling for the GS10 Source Investigation* (RMRS, 2000), six automated samplers were installed in the GS10 drainage to synoptically sample[35] storm events during WY2000 (Figure 4-28 and Figure 4-29). This sampling was designed to help determine which sub-drainage areas may be contributing significant actinide load(s) to GS10 by comparing analytical results from all locations for identical runoff events. By sampling the same event at multiple locations as it moves through the drainage, the variations in water quality due to hydrologic conditions should be minimized. In this way, the concentrations can be compared directly with consideration given to sub-drainage size. Statistical inference was used to assess actinide concentrations from the synoptic locations to identify sub-drainage areas with Pu and/or Am contamination.

Statistical inference was also used to assess Pu/Am ratios as an indication that actinide contamination 'enriched' in Am exists in the sub-drainage tributary to that location. Additionally, water-quality correlations for synoptic sample results were compared to correlations from GS10. Correlation comparisons may indicate that actinide contamination reaching GS10 is originating in a specific sub-drainage. Table 4-10 describes the location and rationale for the six synoptic sampling locations.

---

[35] Synoptic sampling is defined as the collection of samples over a broad area at a single given time. For this project, the single given time is defined as the same time period during a specific stormwater runoff event (i.e.) the rising limb).

Figure 4-28. Automated Synoptic Surface Water Monitoring Locations and Corresponding Sub-Drainage Areas Tributary to GS10.

See attached map.

55

Table 4-10. Automated Synoptic Surface-Water Sampling Location Rationale.

Location Code	Location Description (see Figure 4-28)	Rationale
SW023	Co-located with GS10 on S. Walnut Creek just upstream from the B-1 Bypass	This location collected storm-event samples representative of all surface water from the GS10 drainage. Samples collected at GS10 are continuous flow-paced, and therefore cannot be compared directly to the event samples to be collected at the upstream locations. Approximate Drainage Area: 167 acres
SW132	At end of 1400-foot corrugated metal pipe draining 700 area and S. Walnut Cr.west of B991; includes western portion of B991 and any unknown inflows to this pipe from area around B991	At a manmade structure providing a singular outfall to a specific sub-drainage; Approximate Drainage Area:33.3 acres
SW021	Outfall of culvert draining area inside PA downstream from Solar Ponds and surrounding B991	At a manmade structure providing a singular outfall to a specific sub-drainage; specifically areas nearest the Solar Ponds and B991; Approximate Drainage Area: 19.9 acres
SW060	Outfall of corrugated metal pipe draining areas east and south of PSZ; includes areas east of B551	At a manmade structure providing a singular outfall to a specific sub-drainage; Approximate Drainage Area: 25.7 acres
SW022	Eastern end of Central Avenue Ditch before diversion to S. Walnut Cr.	At a manmade structure providing a singular outfall to a specific sub-drainage; specifically areas nearest the 903 Pad; Approximate Drainage Area: 76.7 acres
SW100100	Upstream end of 1400-foot corrugated metal pipe leading to SW132	On a stream just before entering a manmade structure providing a singular outfall to a specific sub-drainage; specifically areas between the 750 Pad and B991; Approximate Drainage Area: 31.5 acres

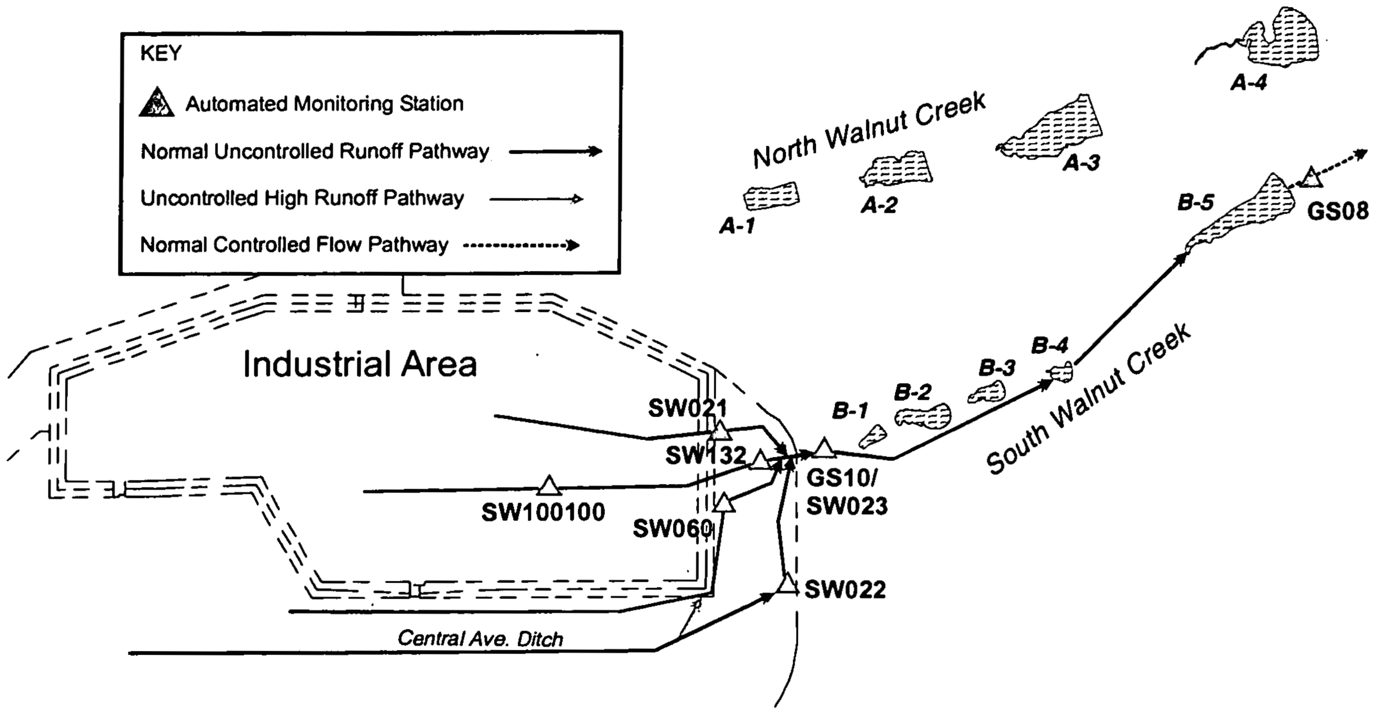


Figure 4-29. Hydrologic Routing Diagram for Automated Synoptic Sampling Locations Tributary to GS10.

4.3.1 Analytical Data Summary

The synoptic locations successfully sampled five runoff events in 2000: April 29-30, June 25, July 16, August 17, and October 22. Table 4-11 and Figure 4-30 both show that the largest average activities were measured at SW023. For most of the sampling events, SW023 also shows the highest Pu and Am activities (see Figure 4-31 through Figure 4-35). This information supports the hypothesis of a source term in the main S. Walnut Cr. stream reach south of B995. Specific event characteristics as related to the analytical results are discussed in Section 4.3.3.

Table 4-11. Summary Statistics for Samples from Automated Synoptic Monitoring Locations Tributary to GS10.

Synoptic Sampling Location	Number of Synoptic Samples	Pu-239,-240		Am-241	
		Average Activity (pCi/l)	Maximum Sample Result (pCi/l)	Average Activity (pCi/l)	Maximum Sample Result (pCi/l)
SW021	5	0.112	0.305	0.129	0.452
SW022	5	0.045[a]	0.089	0.014	0.021
SW023	5	0.653[a]	1.840	0.508	1.240
SW060	5	0.081	0.350	0.157	0.718
SW132	4[b]	0.108	0.198	0.164	0.336
SW100100	5	0.090	0.267	0.170	0.376

Notes: [a] One Pu result rejected through validation.
[b] Equipment failure on one event.

58

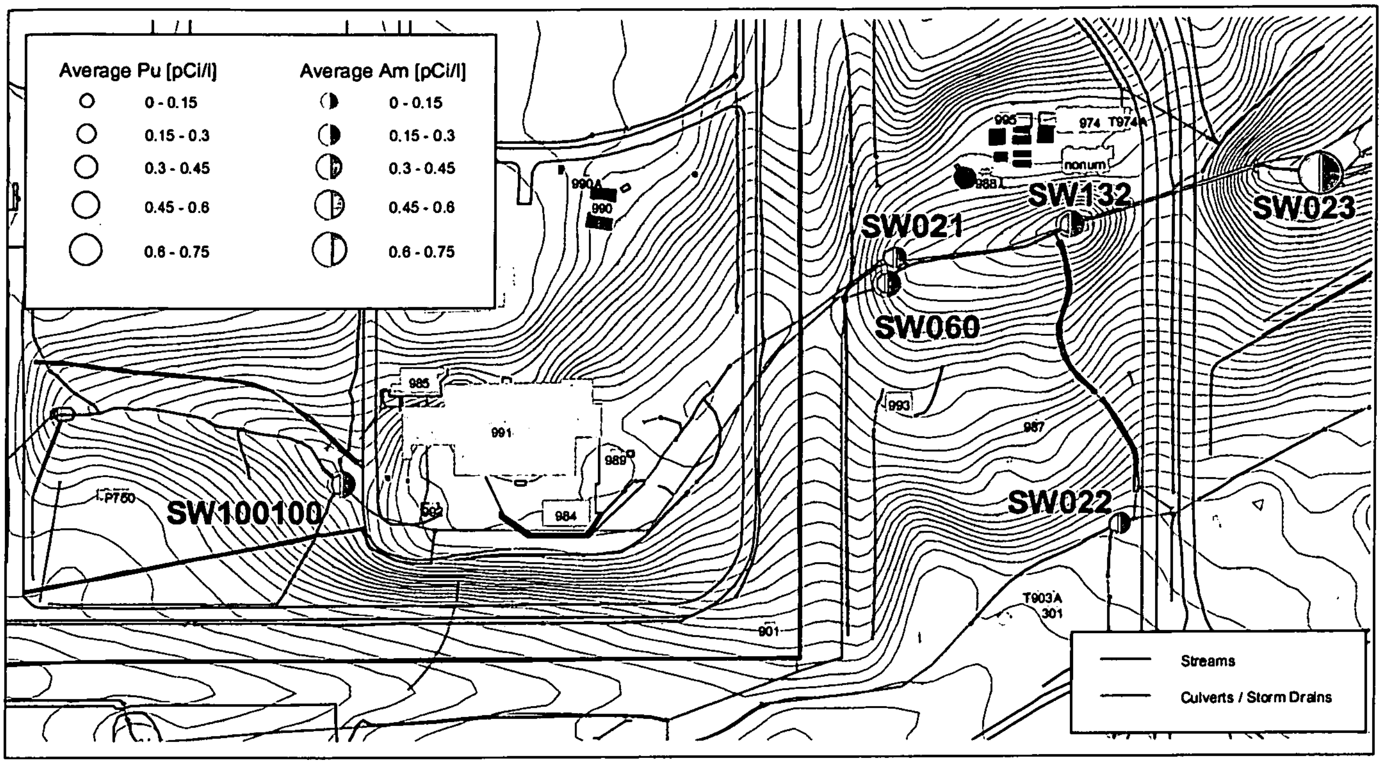
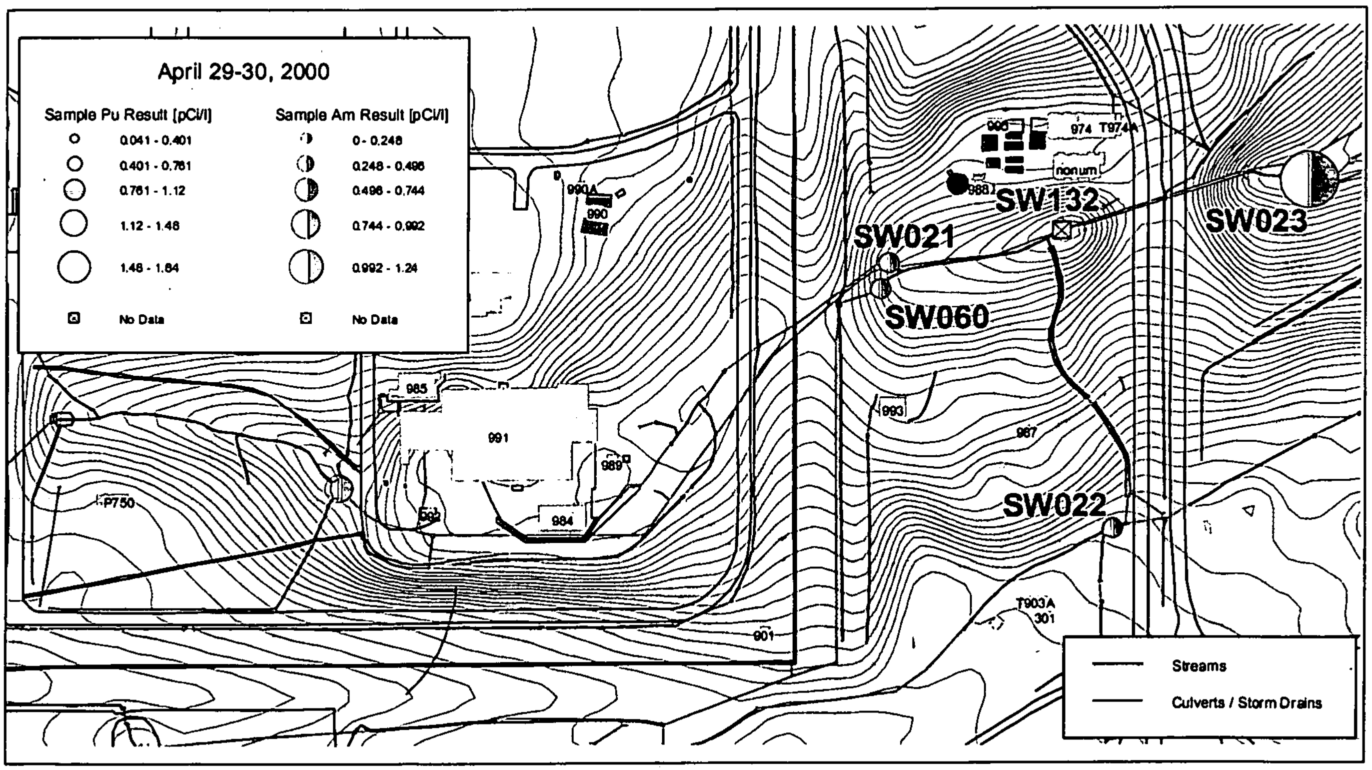


Figure 4-30. Average Pu-239,240 and Am-241 Activities for Synoptic Sampling Locations.



Note: Equipment failure at SW132.

Figure 4-31. Pu-239,240 and Am-241 Activities for April 29-30, 2000 Synoptic Sampling Event.

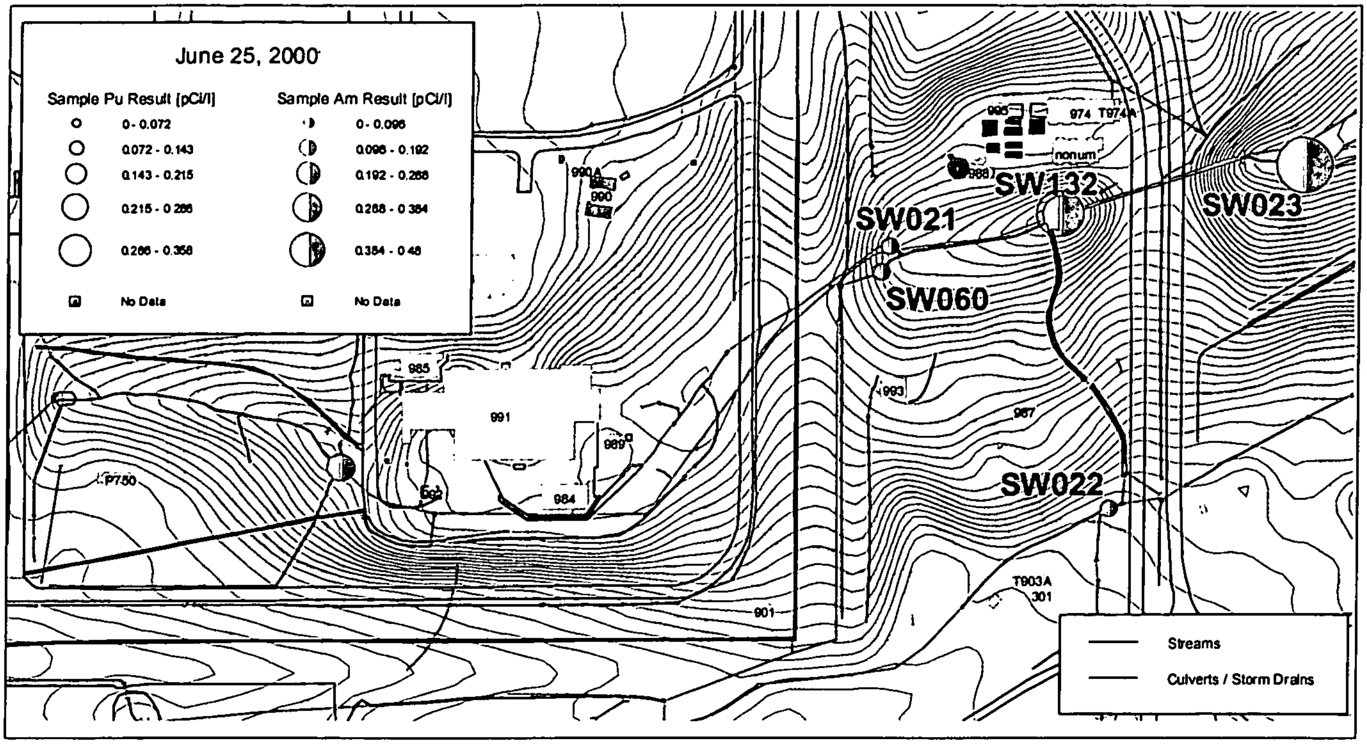


Figure 4-32. Pu-239,240 and Am-241 Activities for June 25, 2000 Synoptic Sampling Event.

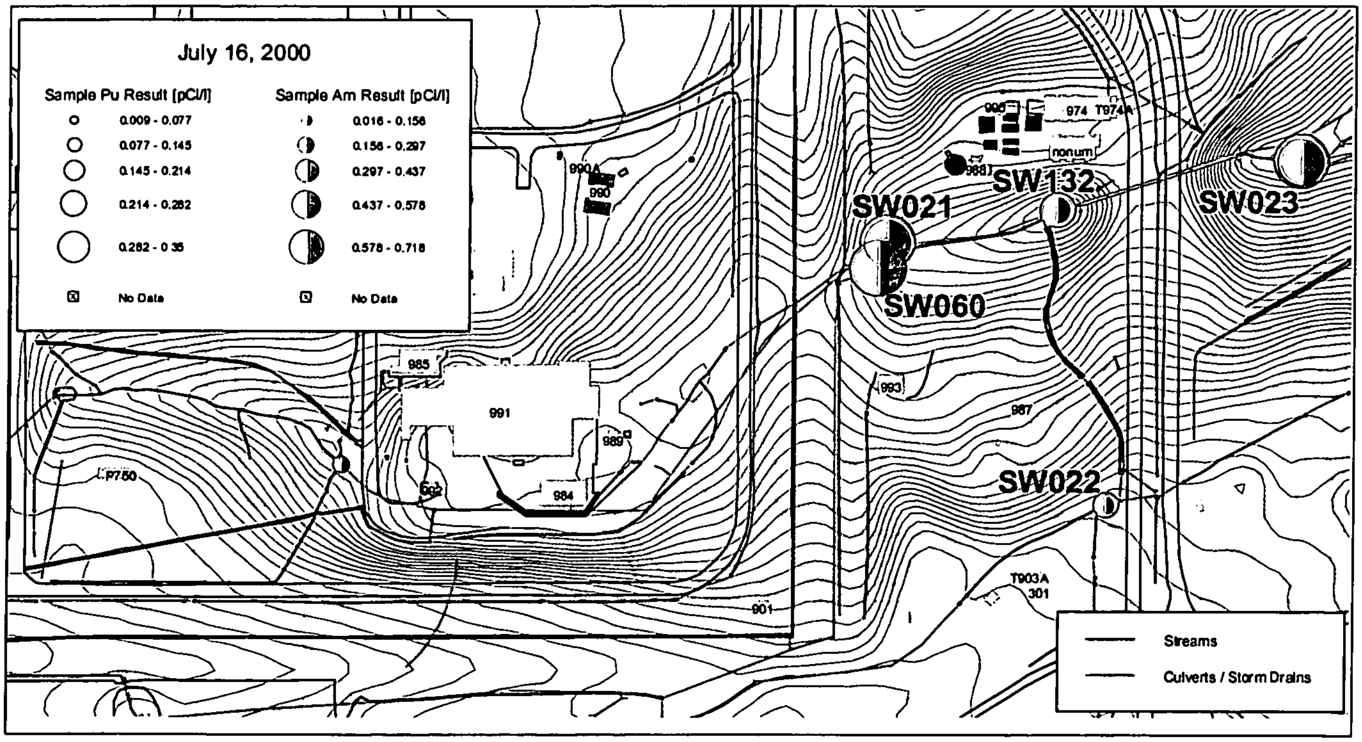
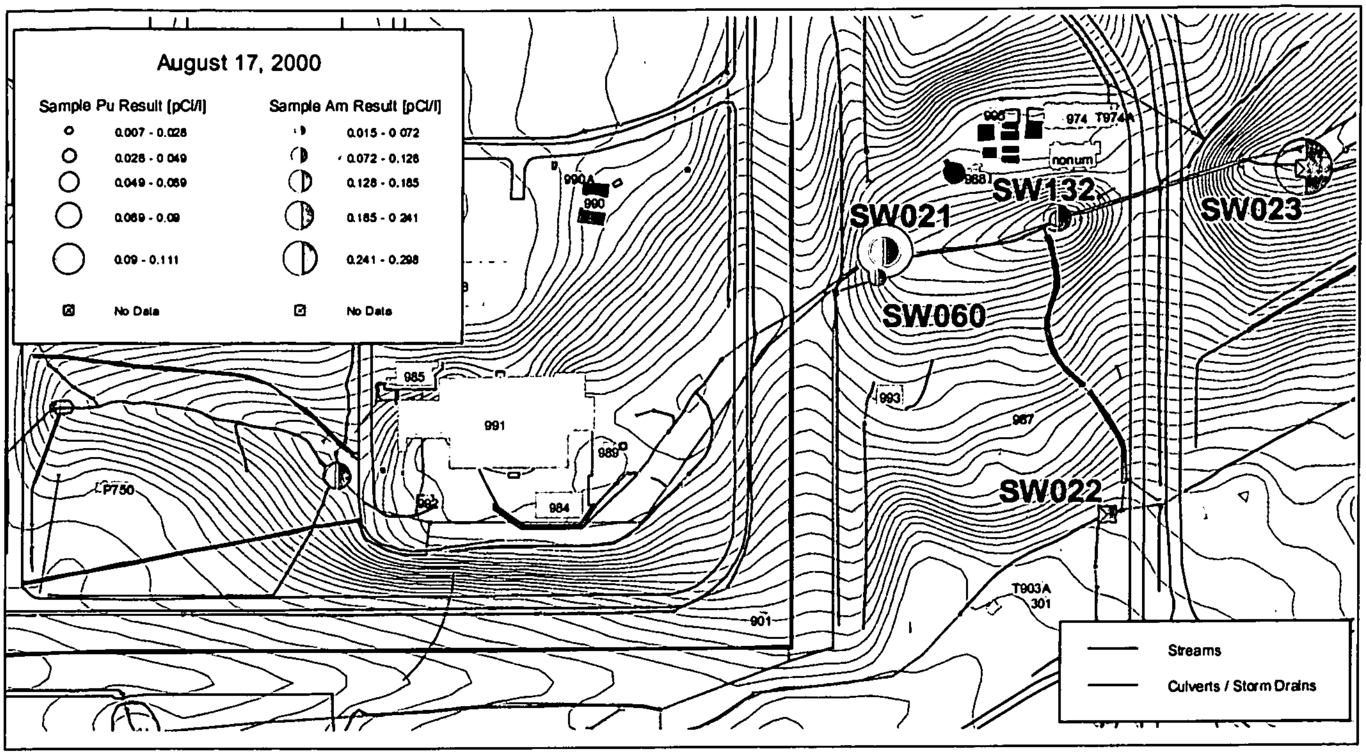


Figure 4-33. Pu-239,240 and Am-241 Activities for July 16, 2000 Synoptic Sampling Event.



Note: Pu results for SW022 and SW023 rejected by validation process.

Figure 4-34. Pu-239,240 and Am-241 Activities for August 17, 2000 Synoptic Sampling Event.

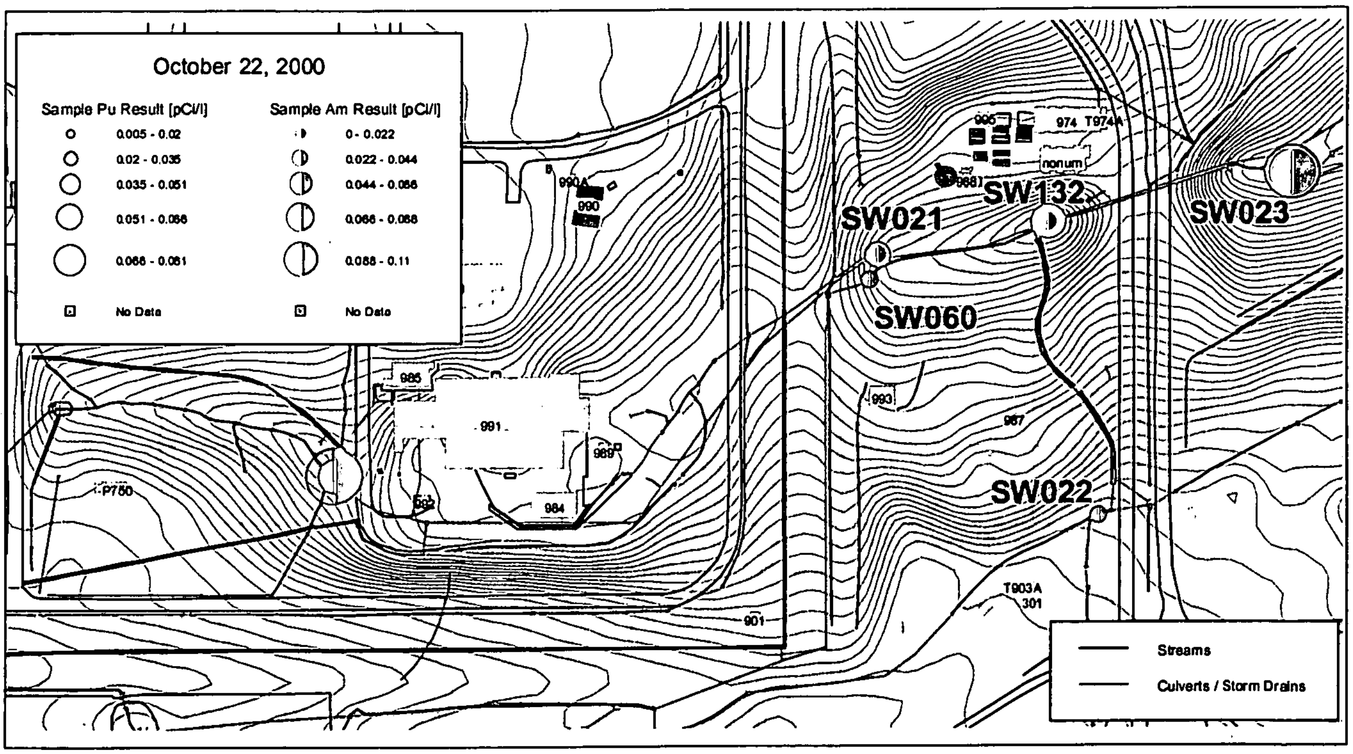


Figure 4-35. Pu-239,240 and Am-241 Activities for October 22, 2000 Synoptic Sampling Event.

61

4.3.2 Pu/Am Activity Ratio Evaluation

Table 4-12 shows that all the synoptic locations have relatively low Pu/Am ratios. These results can generally be explained by the surface-soil and sediment data for sampling locations that are tributary to each synoptic location (see Section 4.4).

SW023 is on the main S. Walnut Cr. reach, and based on the sediment data for this reach, surface-soil data in the drainage, and the hypothesis of an Am 'enriched' source in the reach, the ratio of about 1.0 expected.

SW022 had no results where both Pu and Am were greater than 0.025 pCi/l. However, the ratio for all the samples is 3.2, an expected value given the surface-soil/sediment data in the drainage and the proximity of SW022 to the 903 Pad.

The low Pu/Am ratio at SW021 is likely the result of flows reaching SW021 from the areas east of the Solar Ponds. Surface-soil data from the yard east of the Solar Ponds and sediment data from tributary ditches (specifically south of the Solar Ponds and within the PSZ) show low Pu/Am ratios. Additionally, the lowest Pu/Am ratio at SW021 (0.67) was for the largest runoff event (7/16/00) when overland flow from these areas is most likely to occur.

The low Pu/Am ratio for SW060 is also for the large 7/16/00 event. During smaller events (with less overland flow from pervious areas) the majority of the runoff reaching SW060 would likely originate from paved areas in the 500 Area and near Portal 1, where surface-soil/sediment data from ditches show higher Pu/Am ratios. However, larger events would be expected to produce runoff from pervious areas just east of the PSZ (see Figure 4-28 SW060 drainage area). Although only one sediment result exists for these areas (1.47 Pu/Am ratio), these areas may include low Pu/Am ratio sediments based on their proximity to the PSZ and Solar Ponds.

SW100100 is located on the main S. Walnut Cr. reach. Based on the sediment data for this reach, surface-soil data in the drainage, and the hypothesis of an Am 'enriched' source in the reach, the low Pu/Am ratio of less than 1.0 is expected.

Table 4-12. Summary of Pu/Am Ratios for Samples from Automated Synoptic Monitoring Locations Tributary to GS10.

Synoptic Sampling Location	Number of Synoptic Samples[a]	Average Ratio	Maximum Ratio	Minimum Ratio
SW021	4	1.23	1.67	0.68
SW022	0[b]	NA	NA	NA
SW023	4[c]	1.02	1.48	0.74
SW060	1	0.49	NA	NA
SW132	2[d]	0.76	1.01	0.52
SW100100	4	0.49	0.71	0.31

Notes: [a] Samples where both Pu and Am results were greater than or equal to 0.025 pCi/l.
[b] One Pu result rejected through validation. No samples had results for both Pu and Am ≥ 0.025 pCi/l.
[c] One Pu result rejected through validation.
[d] Equipment failure on one event.

SW132 is on the downstream end of a 1400-foot culvert that runs from west of B991 (at SW100100), under the PSZ, to S. Walnut Cr. south of B995. Although one would expect activities (and ratios) at SW132 to be similar to

62

SW100100, measurable differences are seen for the sampled events. Additionally, TSS is higher at SW132 for most of the events. There are some minor known inflows to the culvert downstream of SW100100 such as storm grates near B991. However, if the integrity of this culvert has been compromised by age and construction projects, then contaminated sediments might be entering the culvert below SW100100.

4.3.3 Water-Quality Correlations

Figure 4-36 shows that TSS increases with increasing peak precipitation intensity for synoptic samples from SW021. Similarly, Figure 4-37 shows that activity increases with increasing TSS. However, for the largest event (7/16/00), activities appear slightly higher for the given TSS and Am activity exceeds Pu activity. This is likely due to the increased load contributions associated with overland flow from the areas near the Solar Ponds (higher overall surface-soil/sediment activities and lower Pu/Am ratios associated with that material).

Figure 4-38 also shows that TSS increases with increasing peak precipitation intensity at SW060. Similarly, Figure 4-39 shows that activity increases with increasing TSS. However, for the largest event (7/16/00), activities are appear higher for the given TSS and Am activity exceeds Pu activity. This is likely due to the increased load contributions associated with overland flow from ditch areas just east of the PSZ.

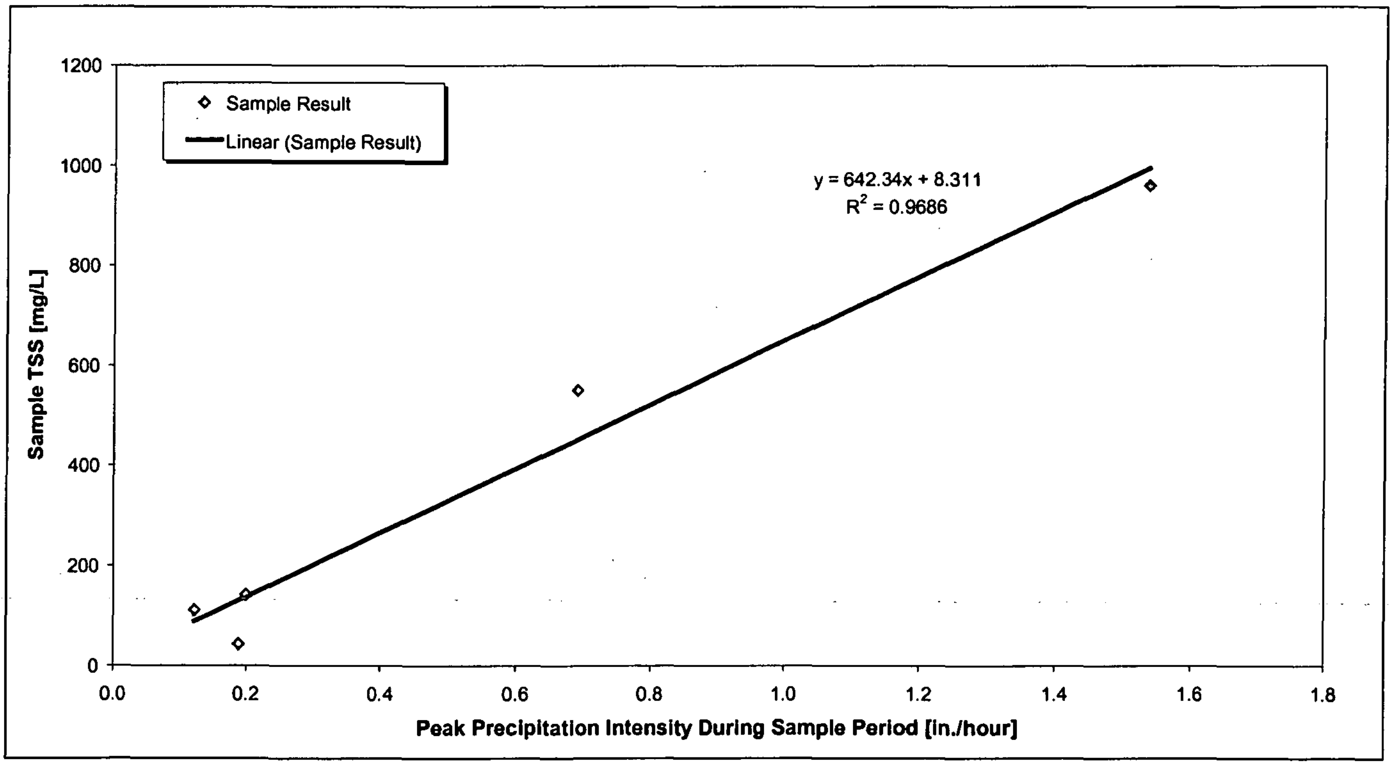


Figure 4-36. Variation of TSS with Peak Precipitation Intensity for Synoptic Samples Collected at SW021.

63

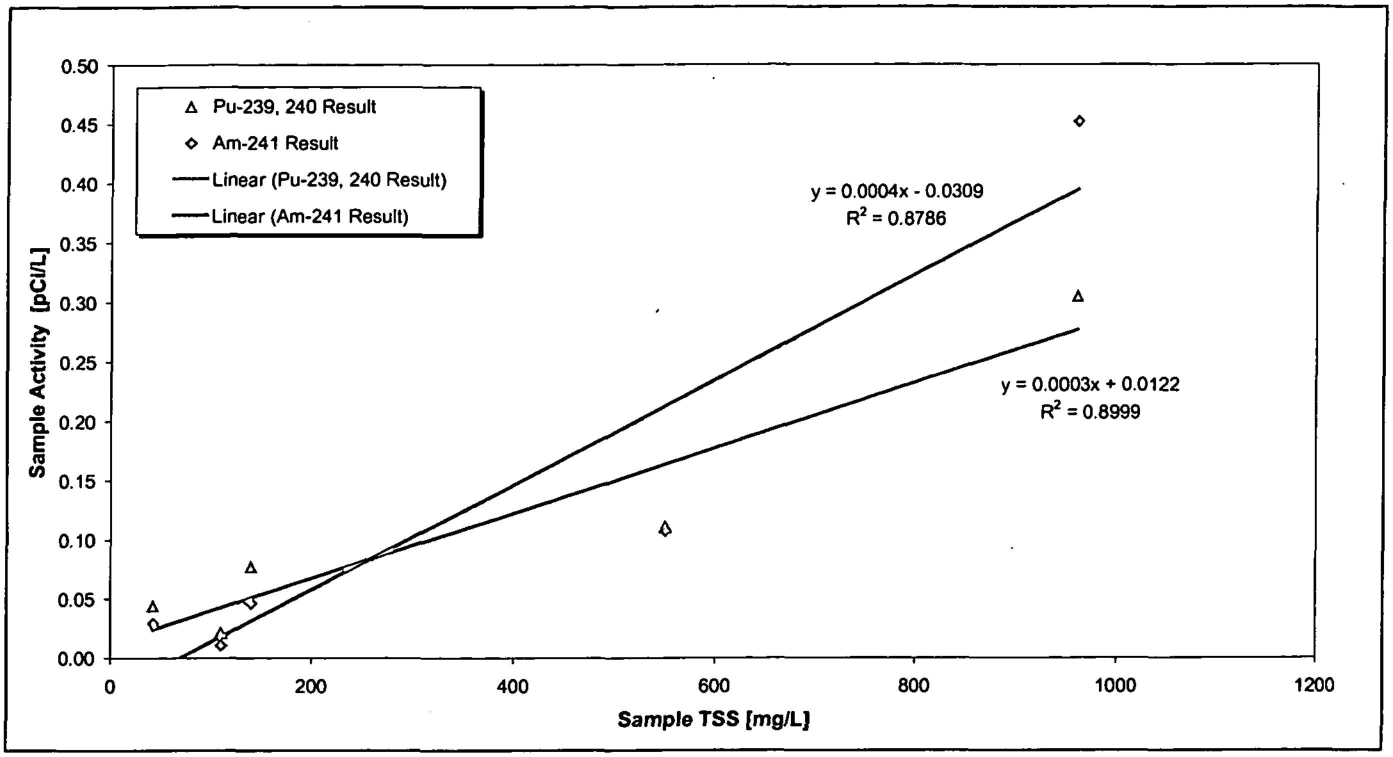


Figure 4-37. Variation of Activity with TSS for Synoptic Samples Collected at SW021.

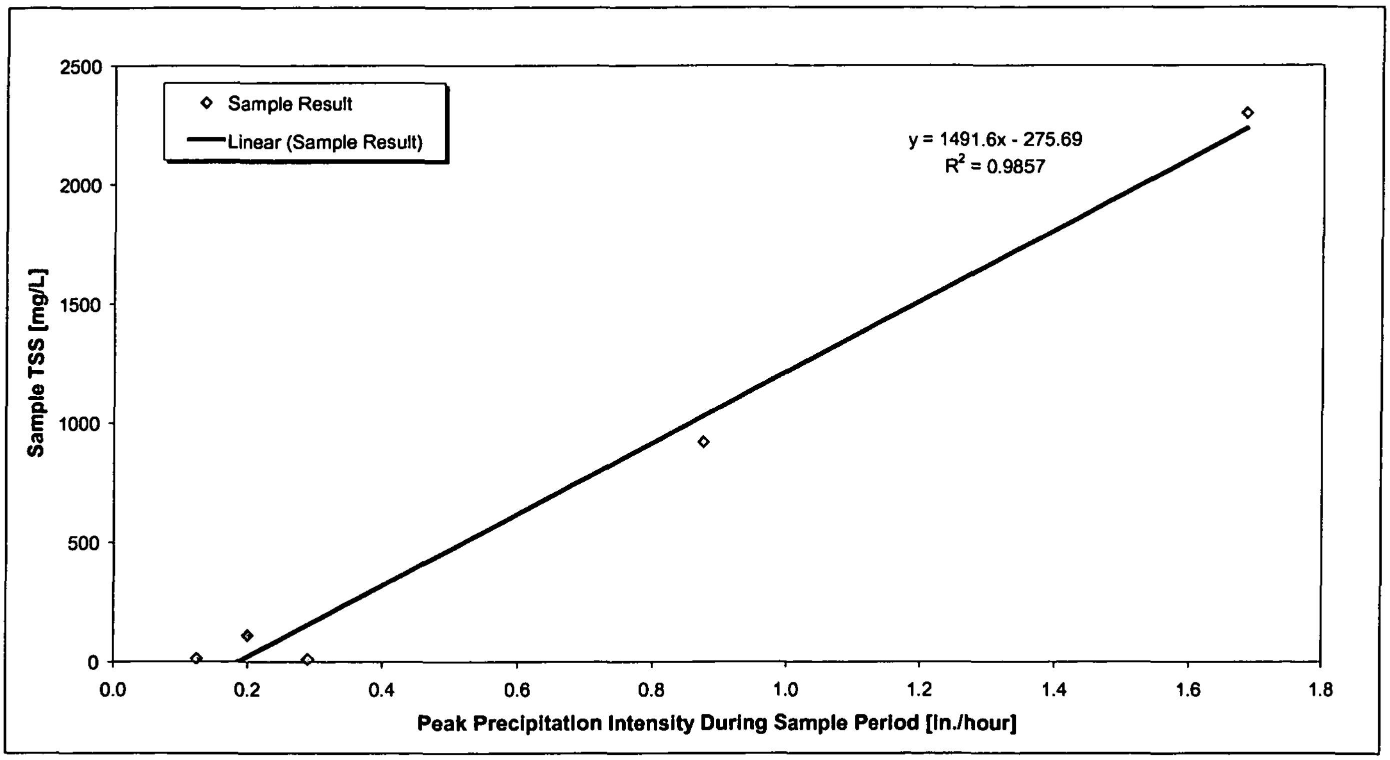


Figure 4-38. Variation of TSS with Peak Precipitation Intensity for Synoptic Samples Collected at SW060.

C24

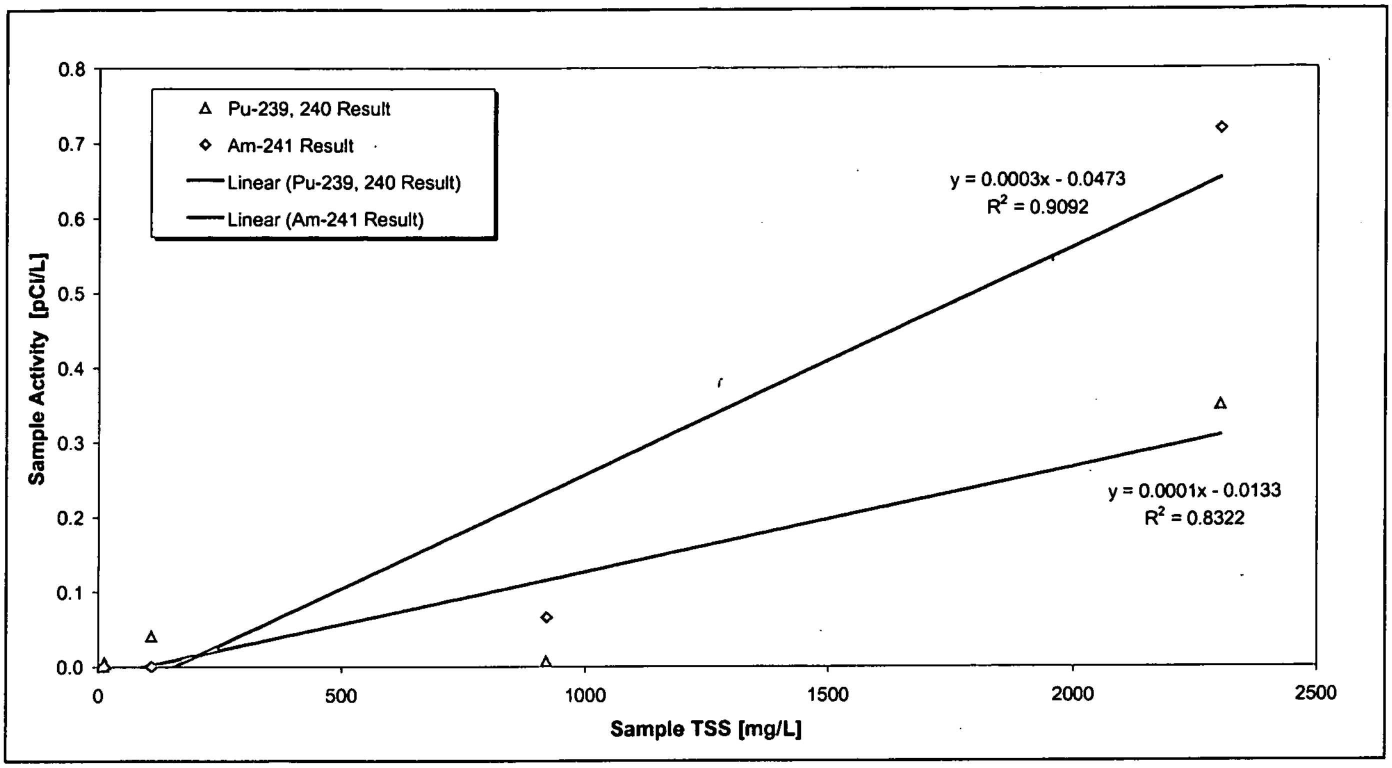


Figure 4-39. Relationship Between Activity and TSS for Synoptic Samples Collected at SW060.

Figure 4-40 shows that TSS does not correlate well with peak precipitation intensity for synoptic samples collected at SW022. Based on the large size of the SW022 drainage (77.7 acres) and the various pervious and impervious areas, variable precipitation patterns would be expected to influence TSS transport.

Sample activity shows a weak correlation with increasing TSS for synoptic samples collected at SW022 (Figure 4-41). Additionally, for all samples collected at SW022, activity shows no correlation with TSS (Figure 4-42). Due to the proximity of the 903 Pad, distributed actinide contamination within the SW022 drainage varies significantly. Some of the highest surface-soil/sediment activities in the SW022 drainage are in the area immediately north of the 903 Pad, and during the Mound and Trench T-1 projects the 3 samples with the highest Pu and Am activities were collected. Therefore, the activity-TSS variability at SW022 is likely the result of spatial variability of actinide contamination and the intermittent disturbance of soils.

For synoptic samples collected at SW022, Figure 4-43 shows no clear correlation between Pu and Am activities.[36] However, for all samples collected at SW022 Figure 4-44 shows a good correlation between Pu and Am (strongly influenced by two points). As discussed previously in this document, the average ratio is 4.3, which is consistent with the hypothesis that SW022 contributes significant Pu load to GS10, but far less Am.

[36] The lack of a clear correlation for these samples is probably due to the low activities and high relative measurement errors.

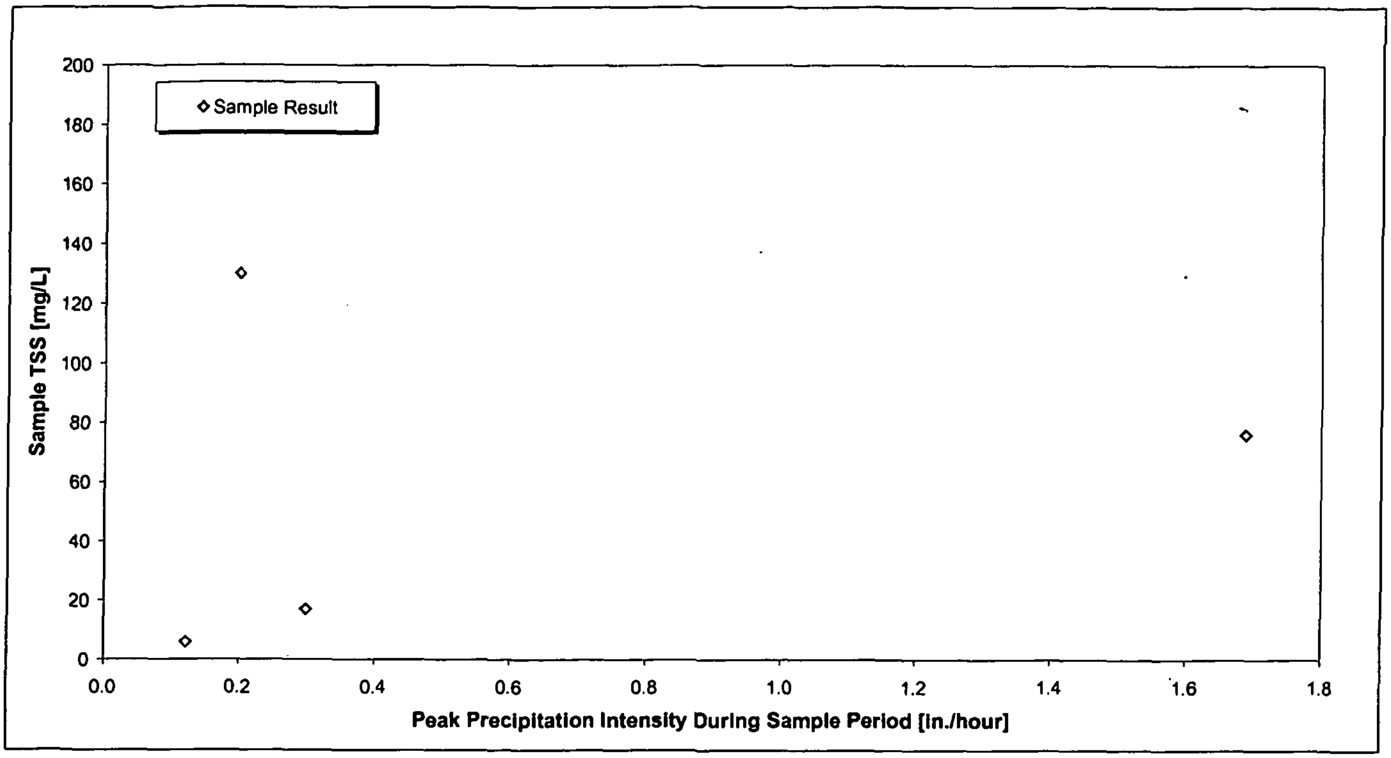


Figure 4-40. Variation of TSS with Peak Precipitation Intensity for Synoptic Samples Collected at SW022.

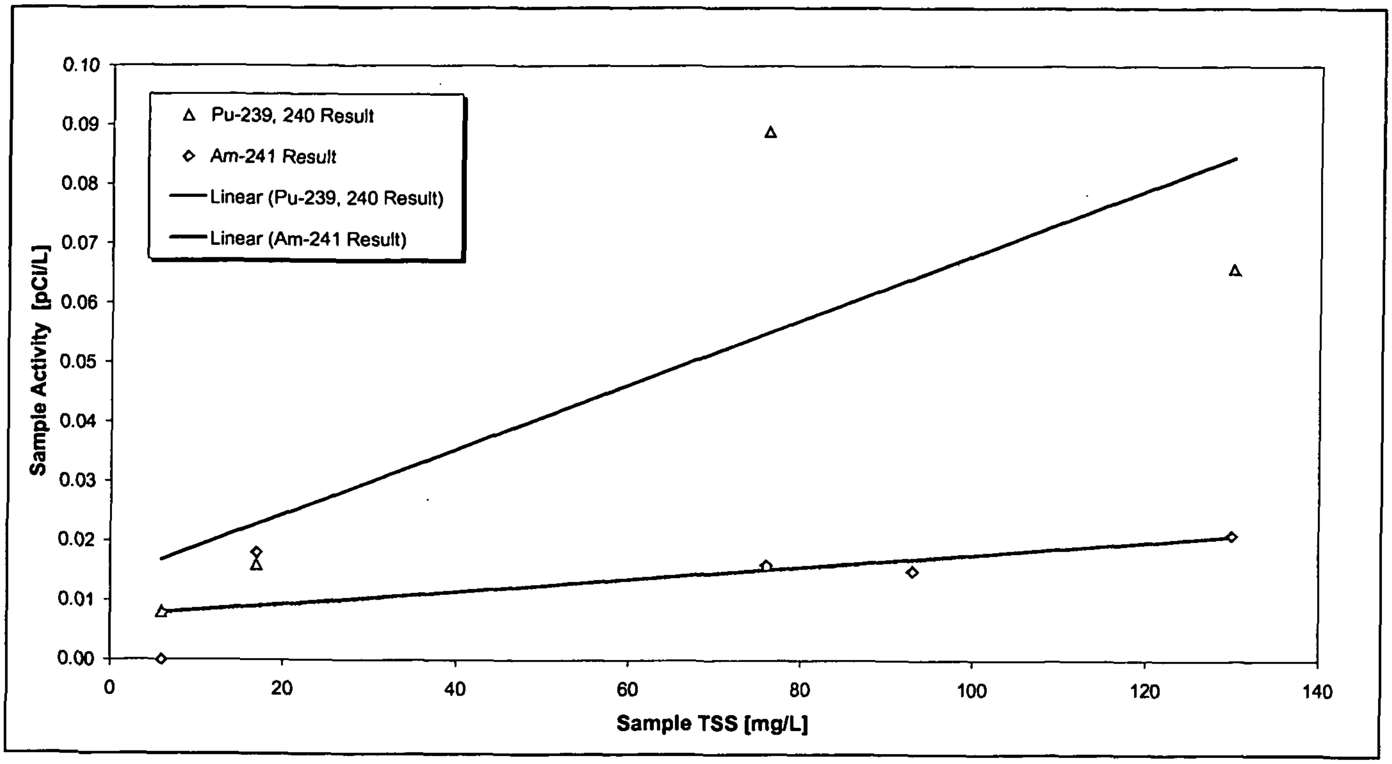


Figure 4-41. Variation of Activity with TSS for Synoptic Samples Collected at SW022.

Ψ

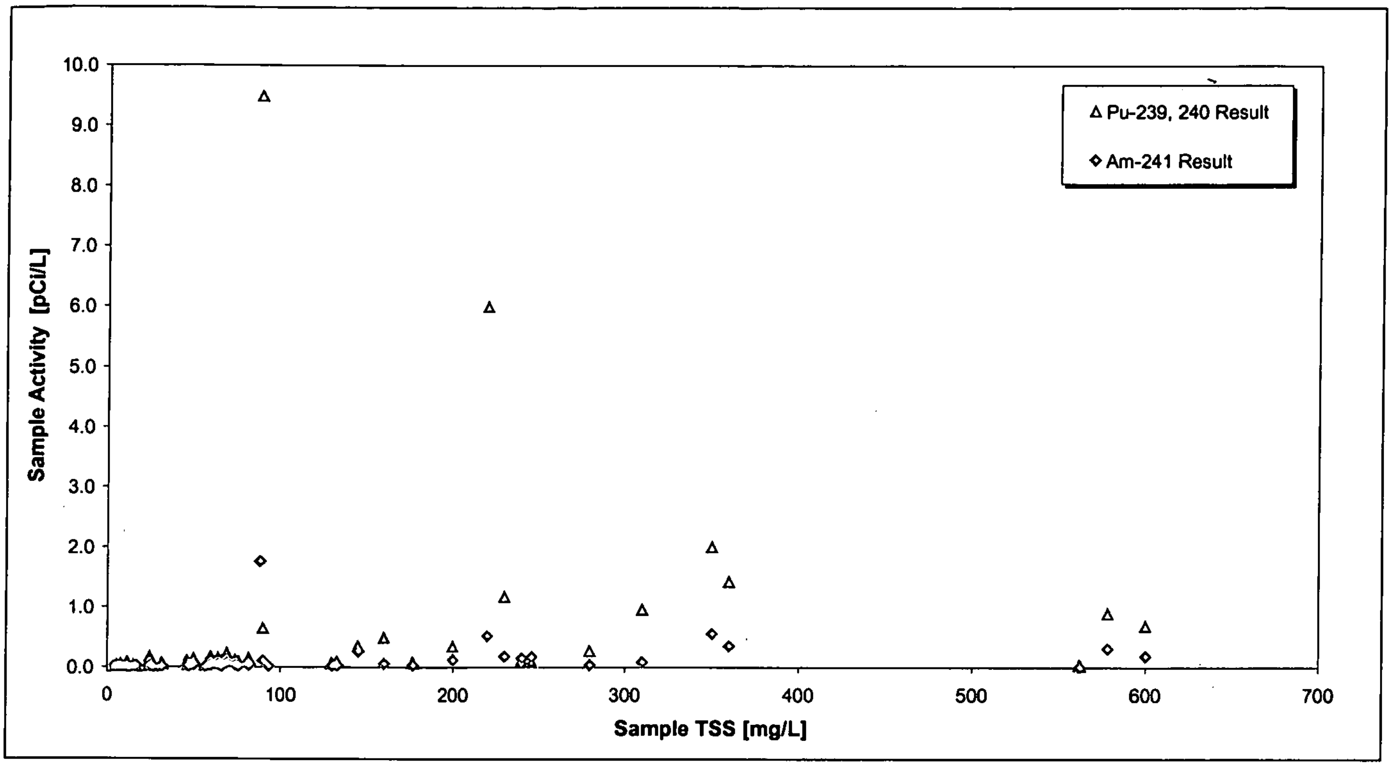


Figure 4-42. Variation of Activity with TSS for All Samples Collected at SW022.

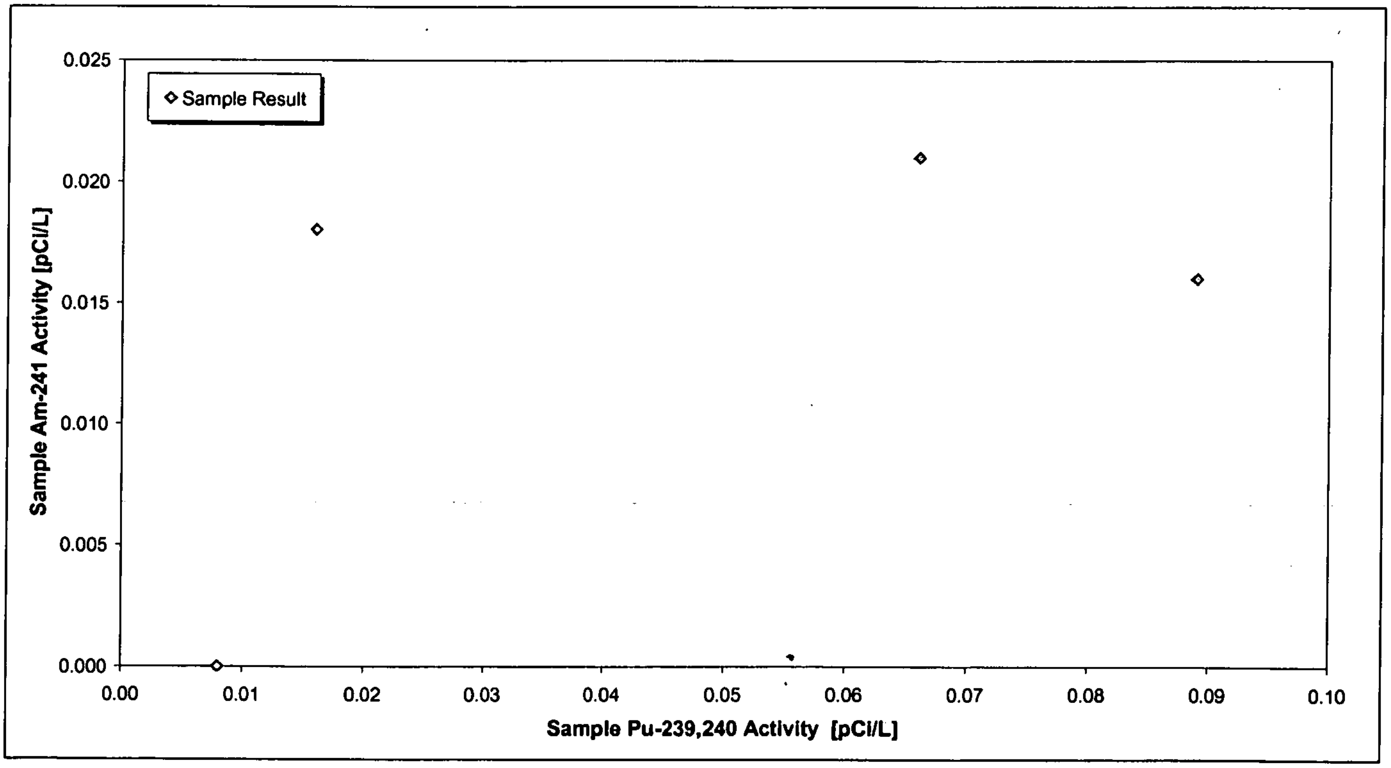


Figure 4-43. Variation of Am-241 with Pu-239, 240 Activities for Synoptic Samples Collected at SW022.

67

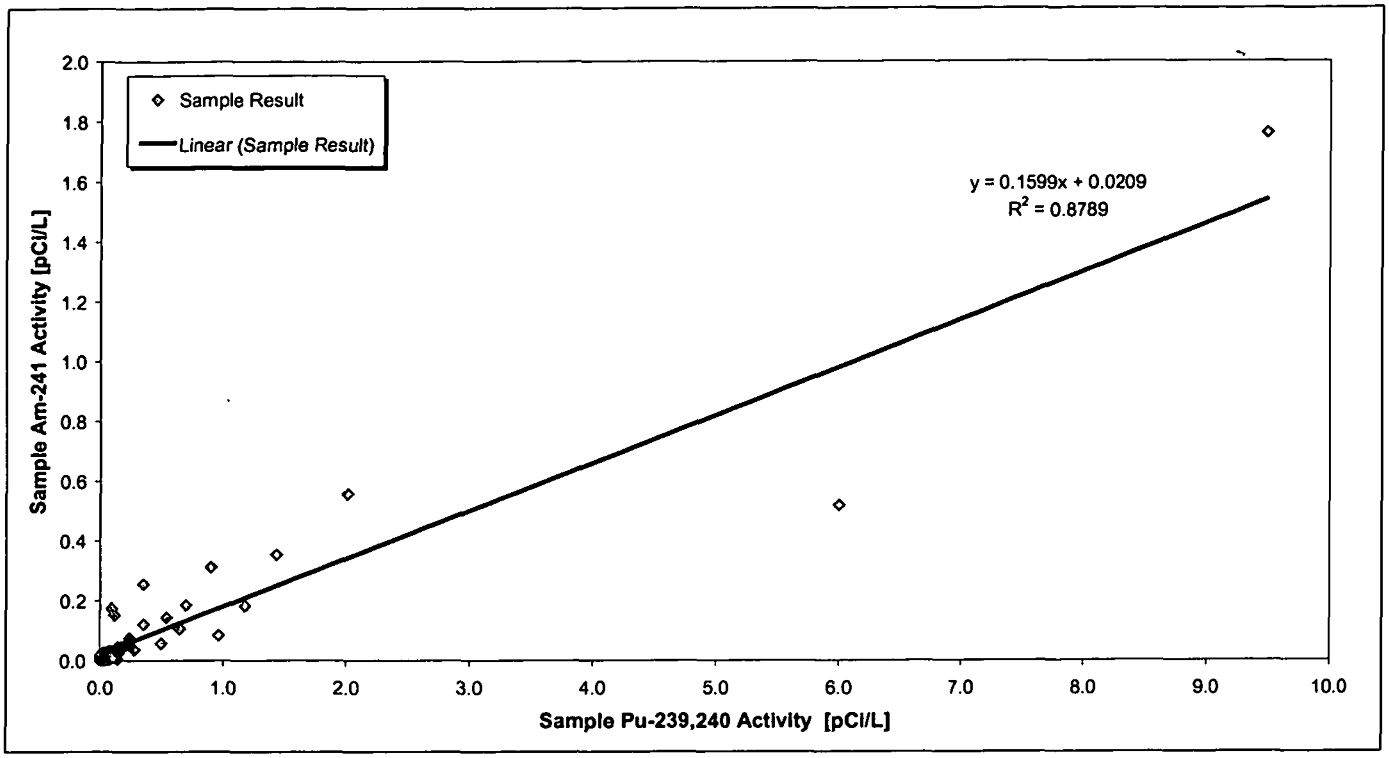


Figure 4-44. Variation of Am-241 with Pu-239, 240 Activities for All Samples Collected at SW022.

As expected, TSS increases with increasing peak precipitation intensity for synoptic samples collected at SW100100 (Figure 4-45). However, the variation of activity with TSS at SW100100 (Figure 4-46) is interesting in the fact that the plot seems to imply a decrease in activity with increasing TSS. Similarly, Figure 4-47 seems to imply that activity also decreases with increasing peak precipitation intensity. This effect may be caused by the existence of an actinide source term that is incorporated into the sediments between GS40 and SW100100. During smaller runoff events, resuspension of sediments could be the main source of actinides at SW100100. However, for larger events increased runoff volumes and relatively less contaminated suspended solids from the 700 Area may be diluting the effects of the resuspended creek sediments. Monitoring data from GS40 (see Section 4.2) show average Pu and Am activities that are an order of magnitude lower than SW100100. While the single sample from GS40 with TSS showed 21 mg/l[37] the TSS values for the SW100100 samples range from 110 to 580 mg/l. Further, Pu/Am ratios at SW100100 are consistently less than 1 (Figure 4-48), with a strong correlation of Am to Pu. In summary, synoptic data from SW100100 is consistent with the hypothesis that the main S. Walnut Cr. stream reach may contain an actinide source incorporated into the sediments that is 'enriched' in Am.

[37] This sample was collected from a fairly large runoff event during the sample period 5/4/01 13:55 to 5/5/01 13:25.

ca 8

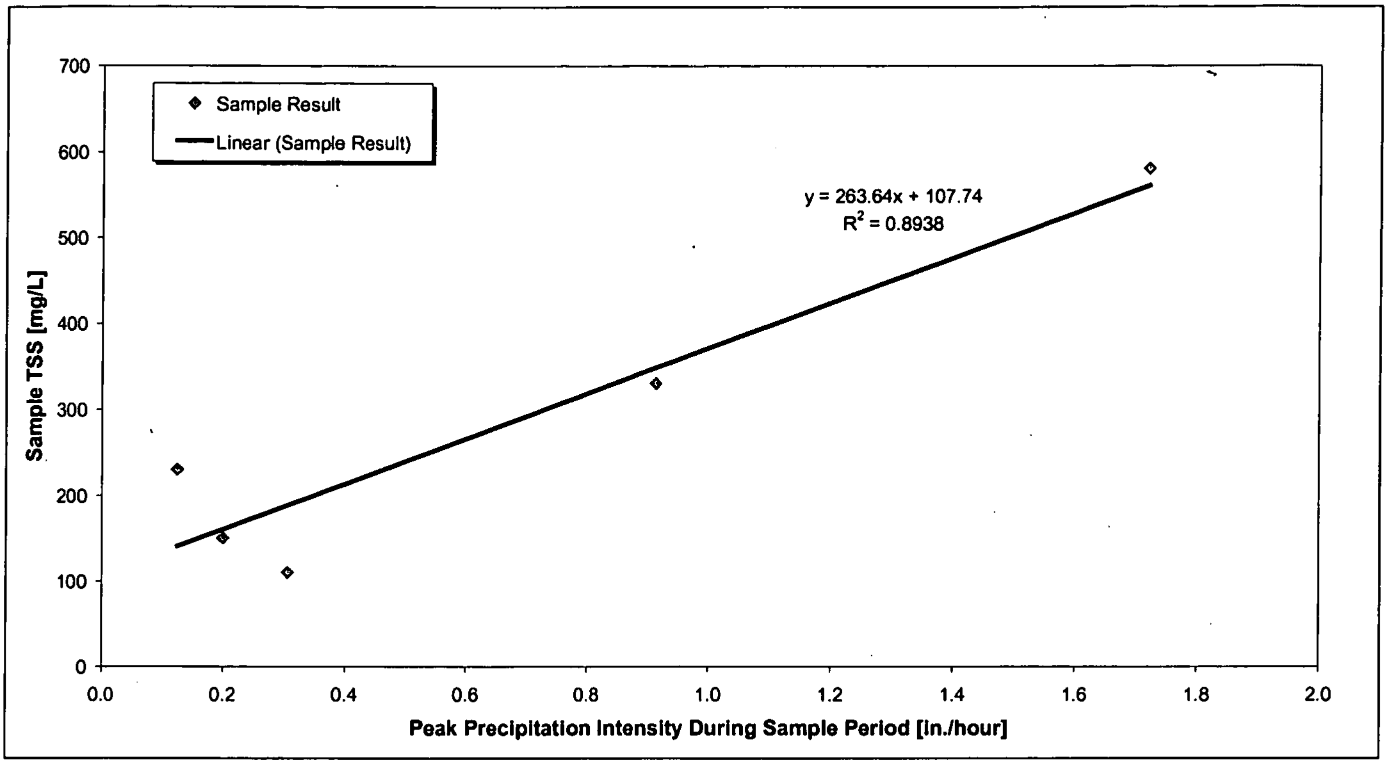


Figure 4-45. Variation of TSS with Peak Precipitation Intensity for Synoptic Samples Collected at SW100100.

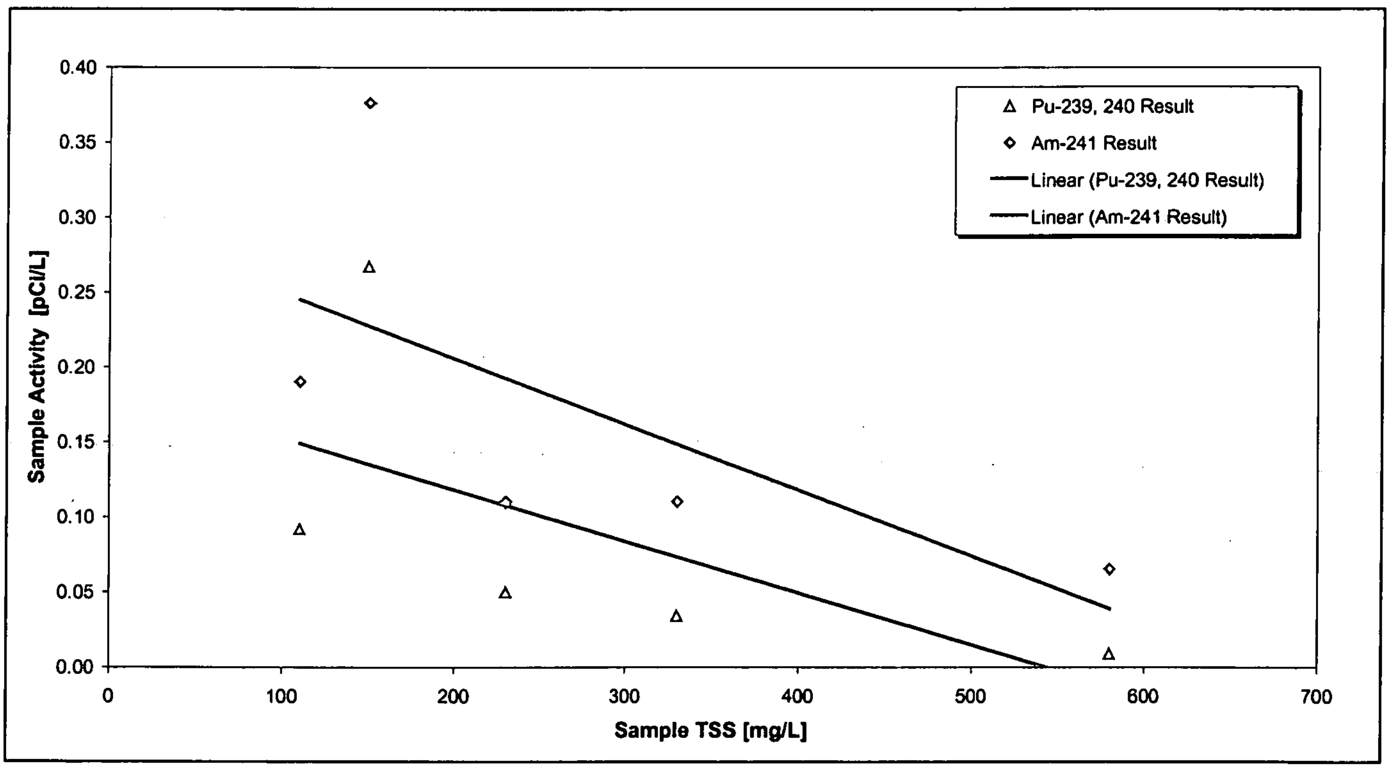


Figure 4-46. Variation of Activity with TSS for Synoptic Samples Collected at SW100100.

69

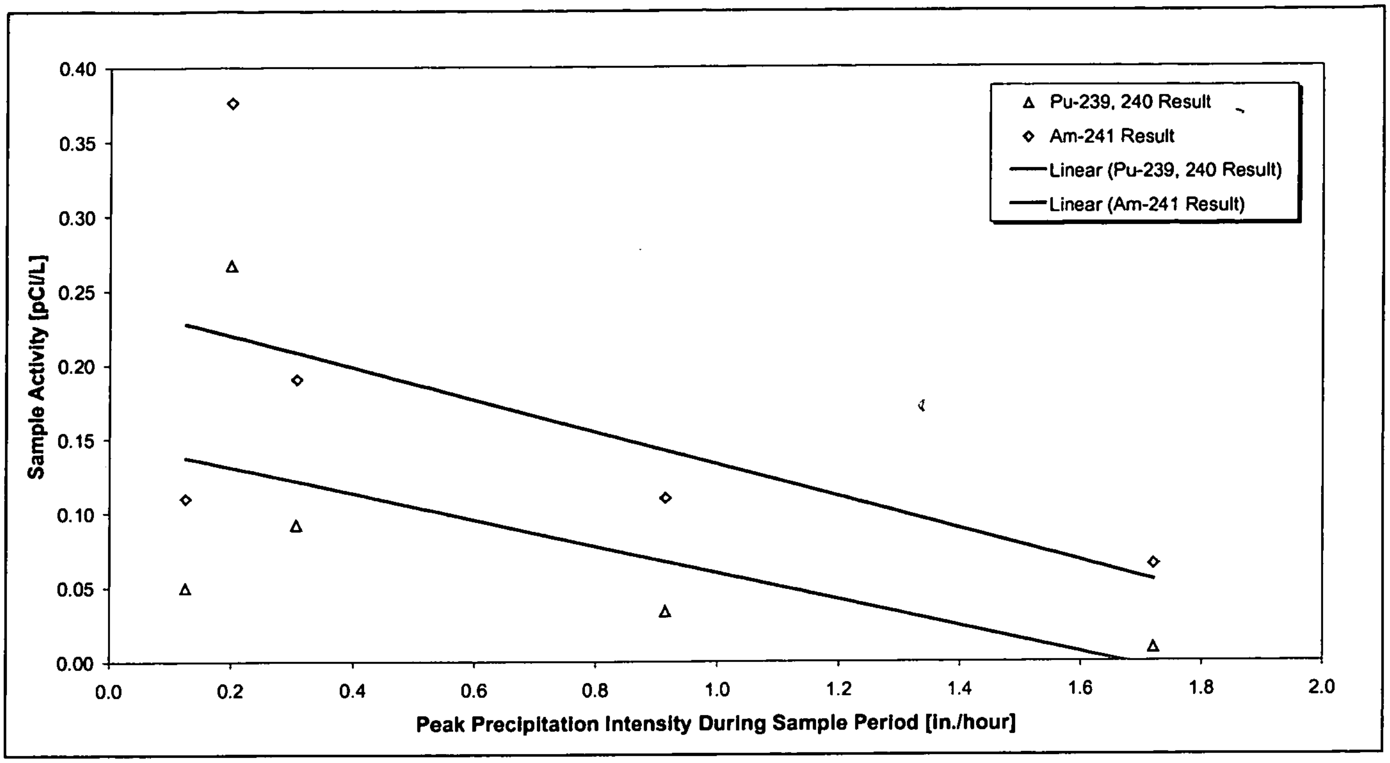


Figure 4-47. Variation of Activity and Peak Precipitation Intensity for Synoptic Samples Collected at SW100100.

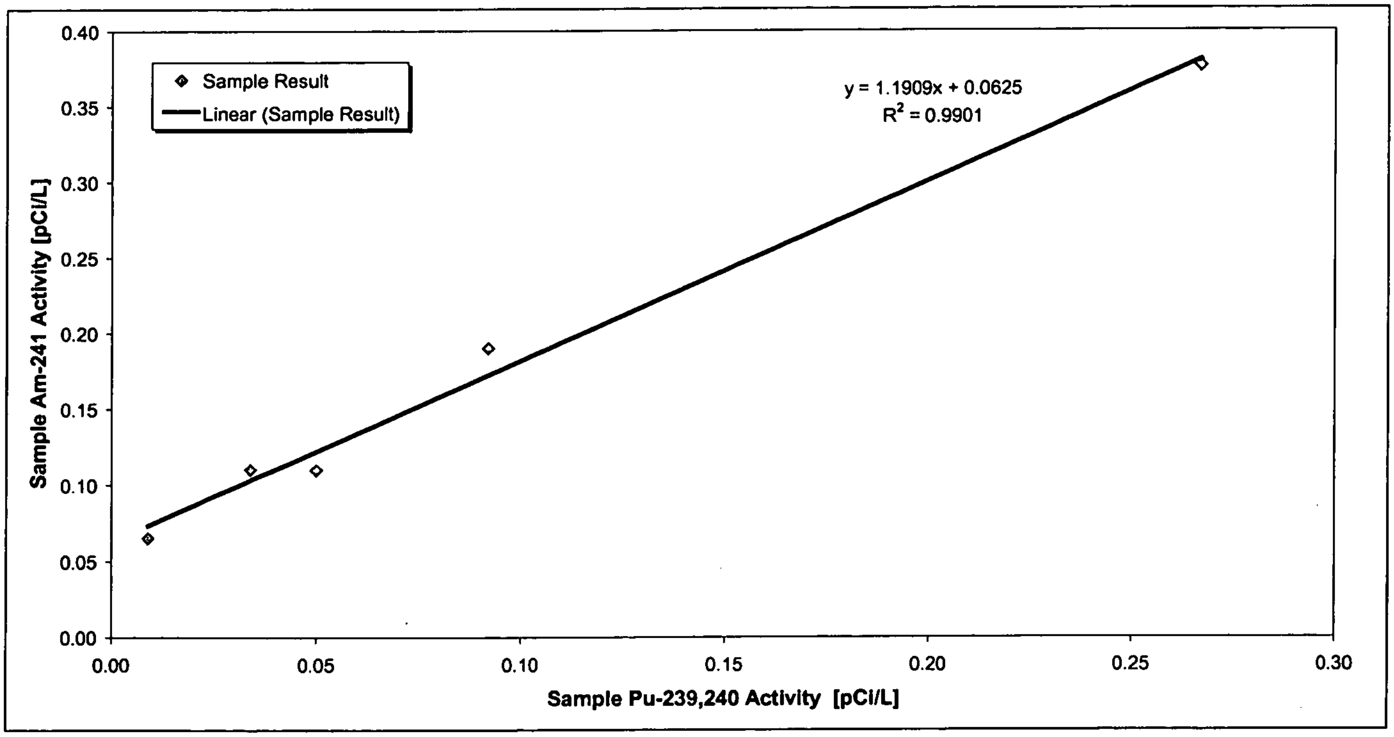


Figure 4-48. Variation of Am-241 with Pu-239, 240 Activities for Synoptic Samples Collected at SW100100.

70

SW132 shows effects similar to SW100100, although not as clearly. This difference may be due to various inputs to the culvert between SW100100 and SW132 from known storm grates and culvert breaches (as discussed in Section 4.3.2). As expected, TSS increases with increasing peak precipitation intensity for synoptic samples collected at SW132 (Figure 4-49). However, activity does not increase with increasing TSS (Figure 4-50). Similarly, activity does not increase with increasing peak precipitation intensity (Figure 4-51). This effect may also be caused by the same dilution effects observed in the SW100100 data.

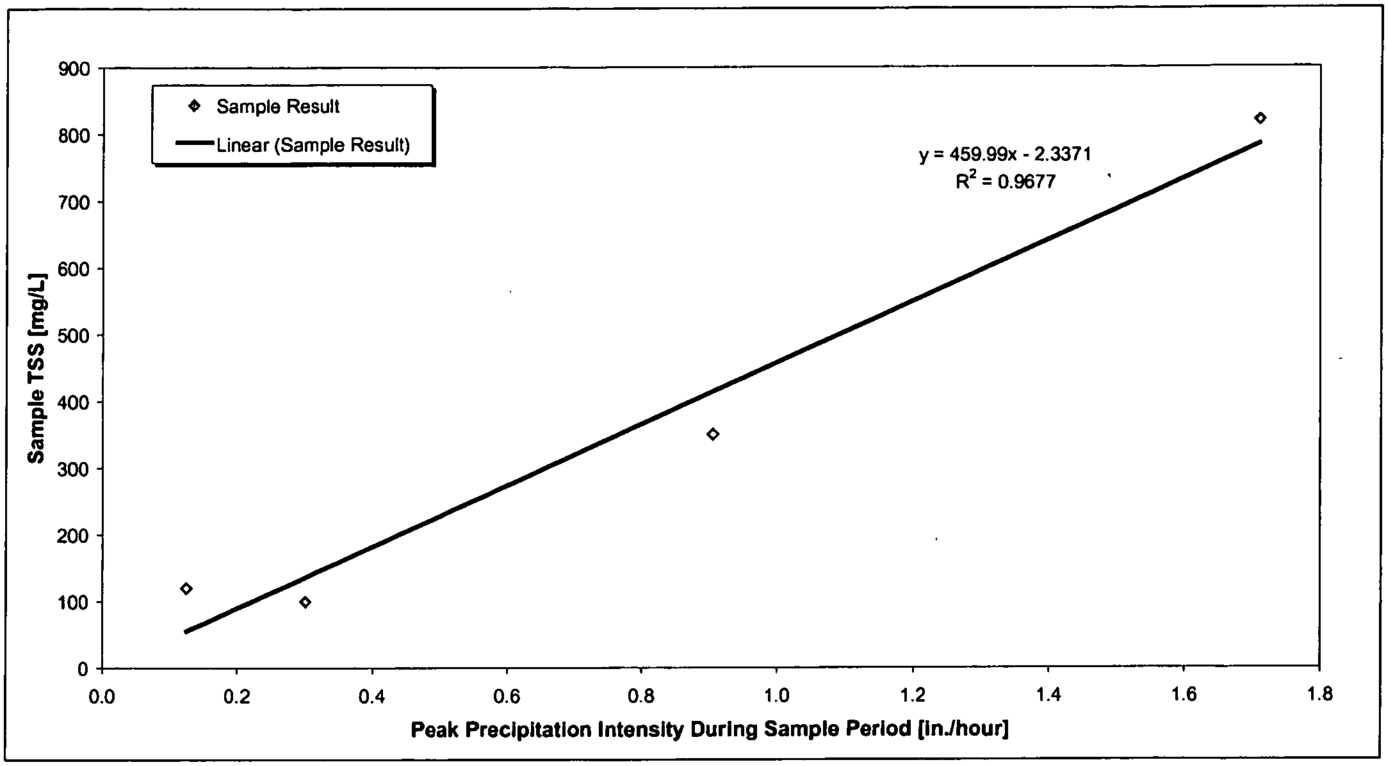


Figure 4-49. Variation of TSS with Peak Precipitation Intensity for Synoptic Samples Collected at SW132.

11

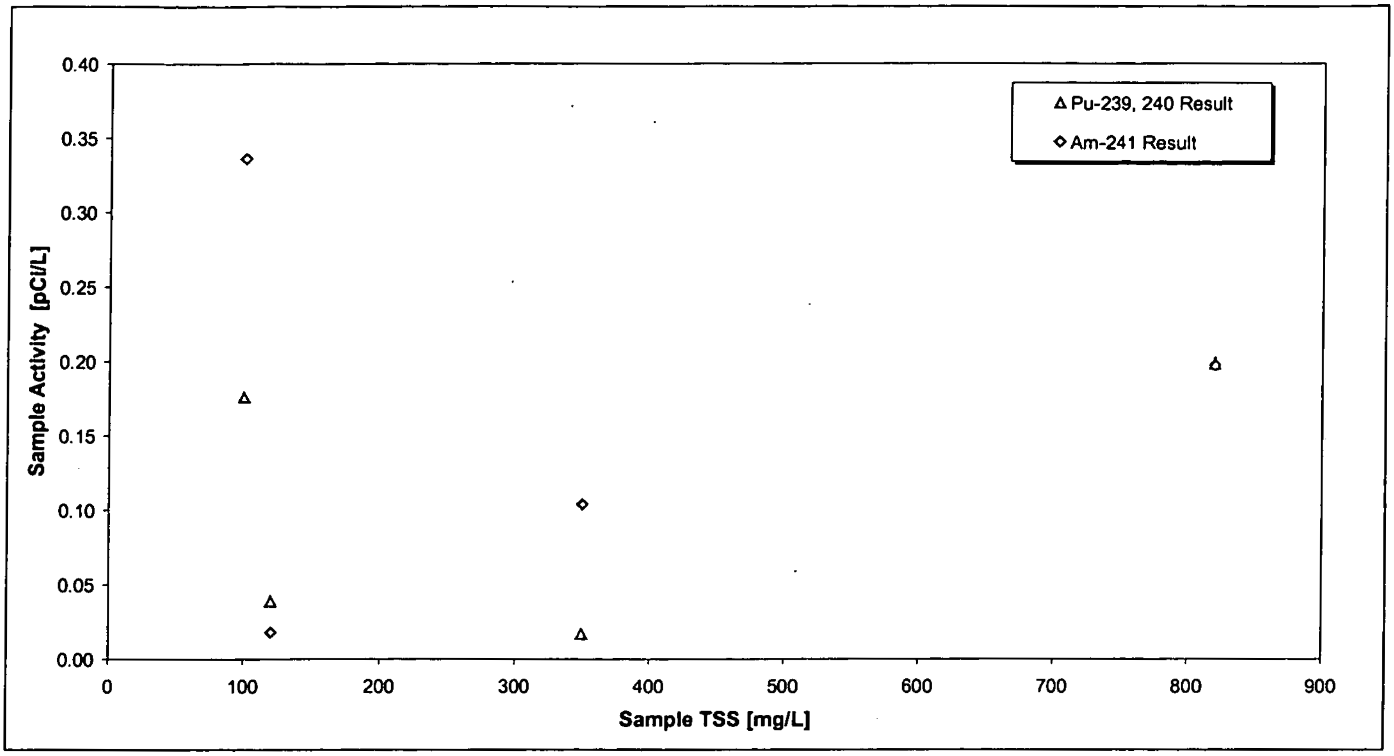


Figure 4-50. Variation of Activity with TSS for Synoptic Samples Collected at SW132.

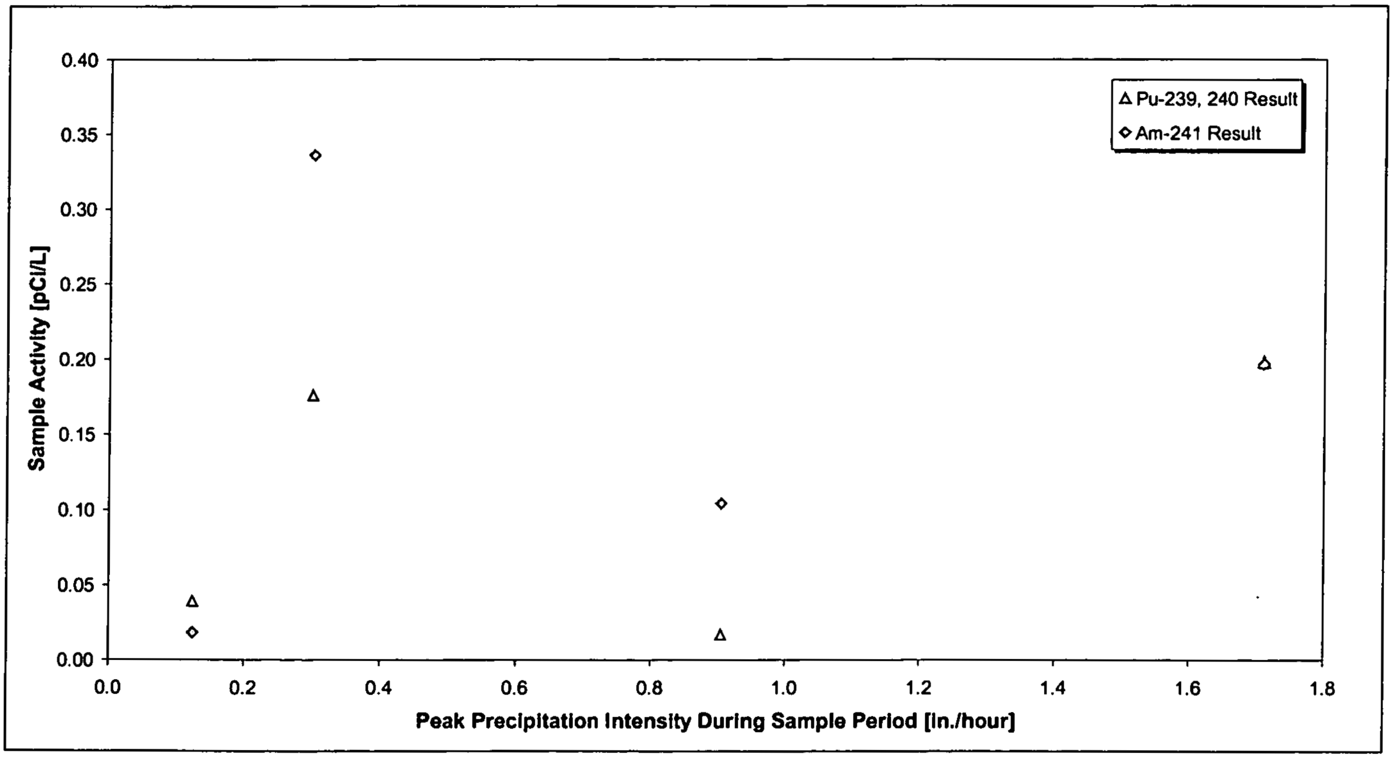


Figure 4-51. Variation of Activity with Peak Precipitation Intensity for Synoptic Samples Collected at SW132.

12

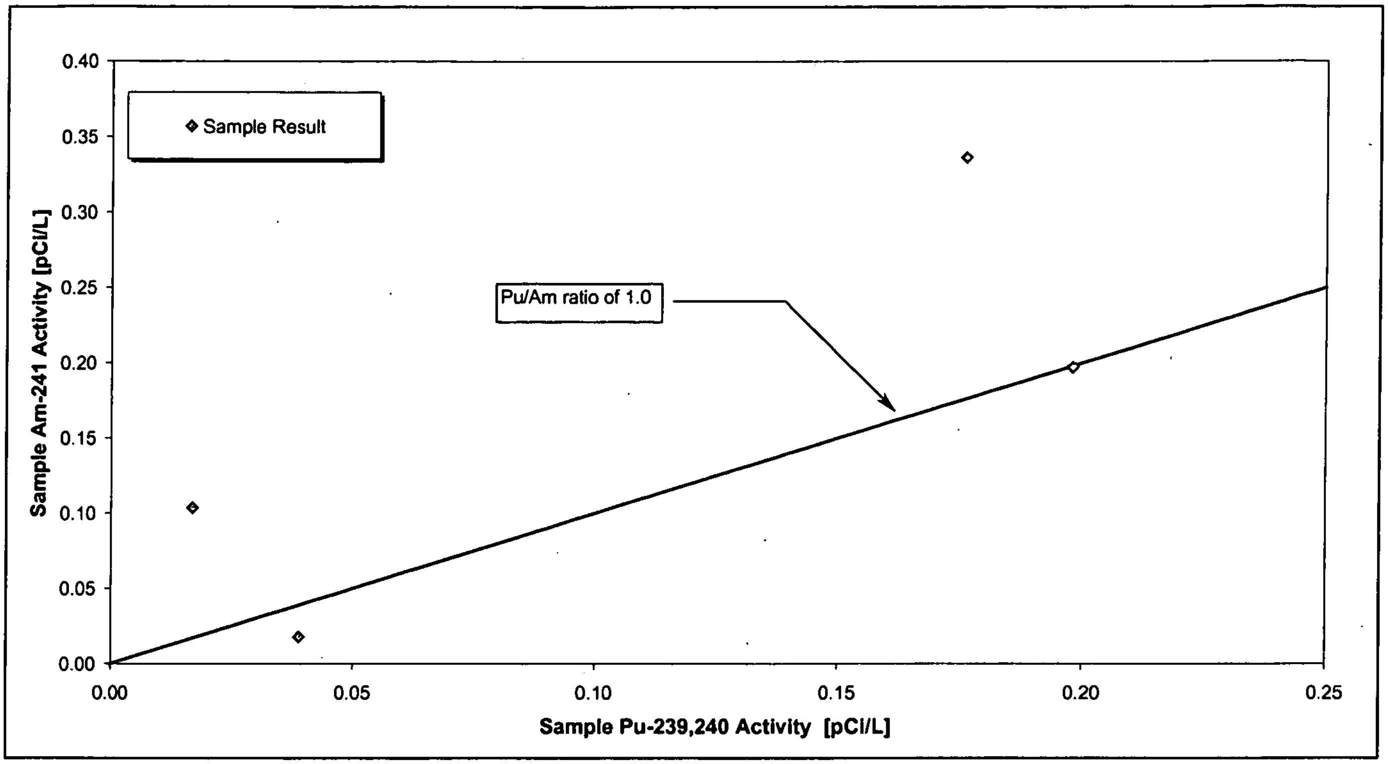


Figure 4-52. Variation of Am-241 with Pu-239, 240 Activities for Synoptic Samples Collected at SW132.

SW023 shows effects similar to SW100100, although not as clearly. This difference is likely due to the confluence of multiple sub-drainage flows upstream of SW023. As expected, TSS increases with both increasing peak precipitation intensity and increasing peak flow for synoptic samples collected at SW023 (Figure 4-53 and Figure 4-54).[38] However, activity does not increase with increasing TSS (Figure 4-55). Similarly, activity does not increase with increasing peak flow (Figure 4-56). This effect may also be caused by the same dilution effects seen at SW100100 as Am-enriched source sediments in the main S. Walnut Cr. stream reach are diluted by the other sub-drainage inflows. Although Figure 4-57 shows a good correlation of Am to Pu for synoptic samples from SW023, data from co-located GS10 show high Am-Pu variability (as discussed extensively above). In summary, synoptic data from SW023 are consistent with the hypothesis that the main S. Walnut Cr. stream reach may contain an actinide source incorporated into the sediments that is enriched in Am.

[38] Flow was collected only for synoptic locations SW023 and SW022.

13

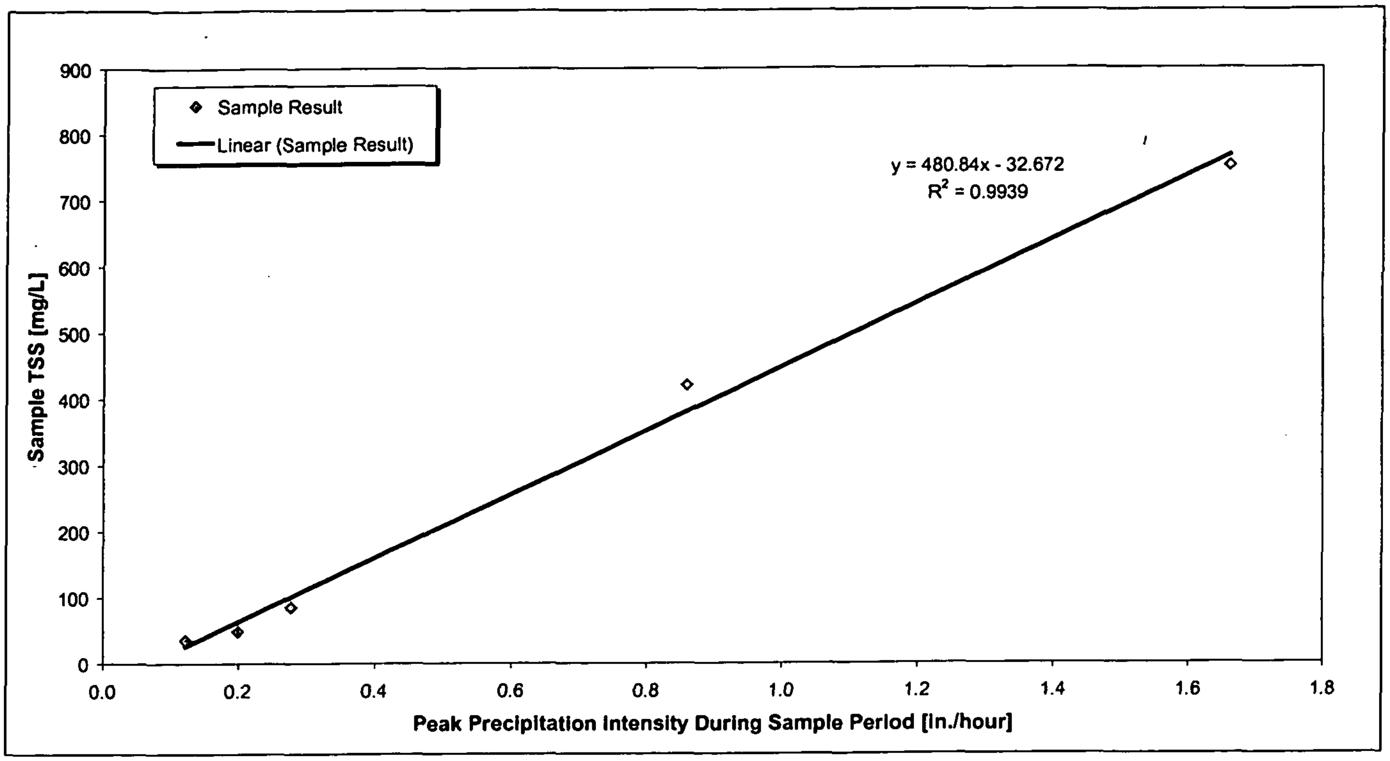


Figure 4-53. Variation of TSS with Peak Precipitation Intensity for Synoptic Samples Collected at SW023.

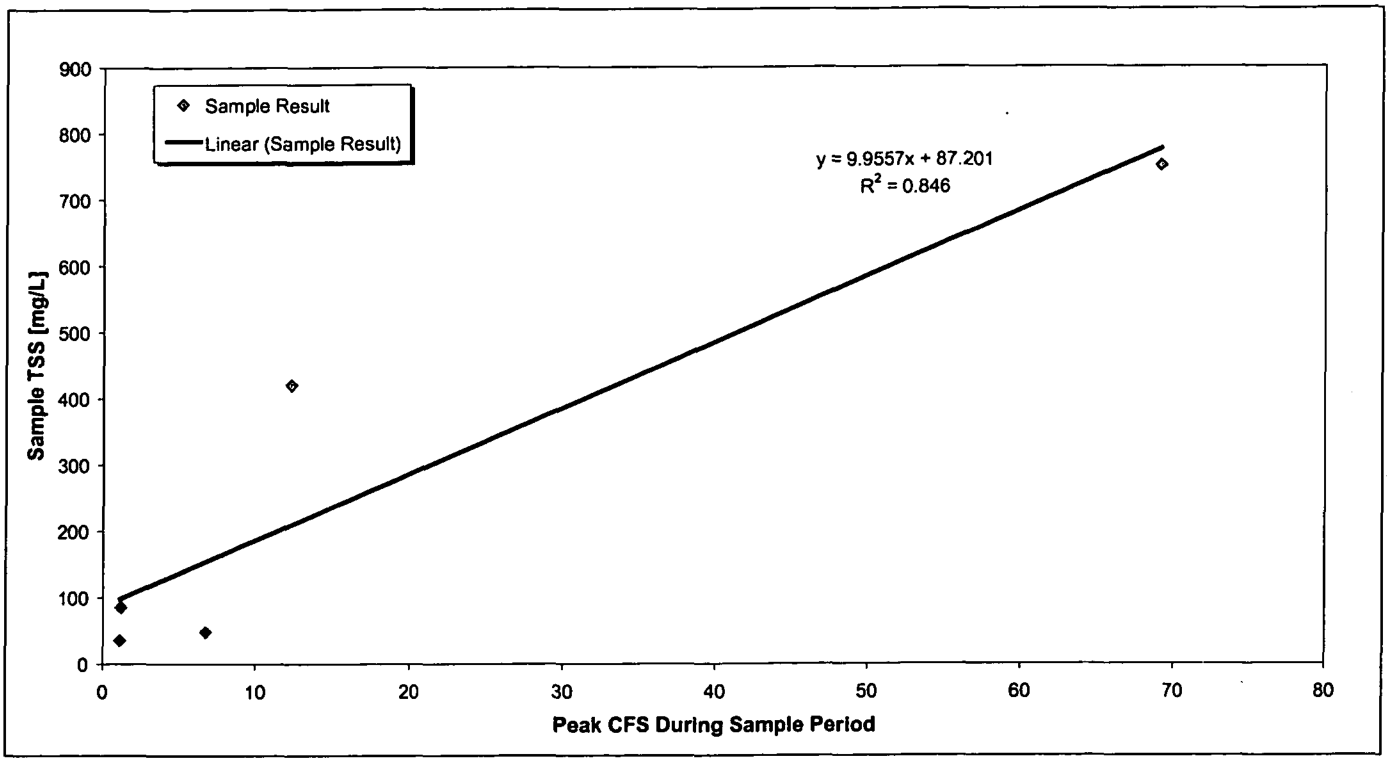


Figure 4-54. Variation of TSS with Peak Flow for Synoptic Samples Collected at SW023.

14

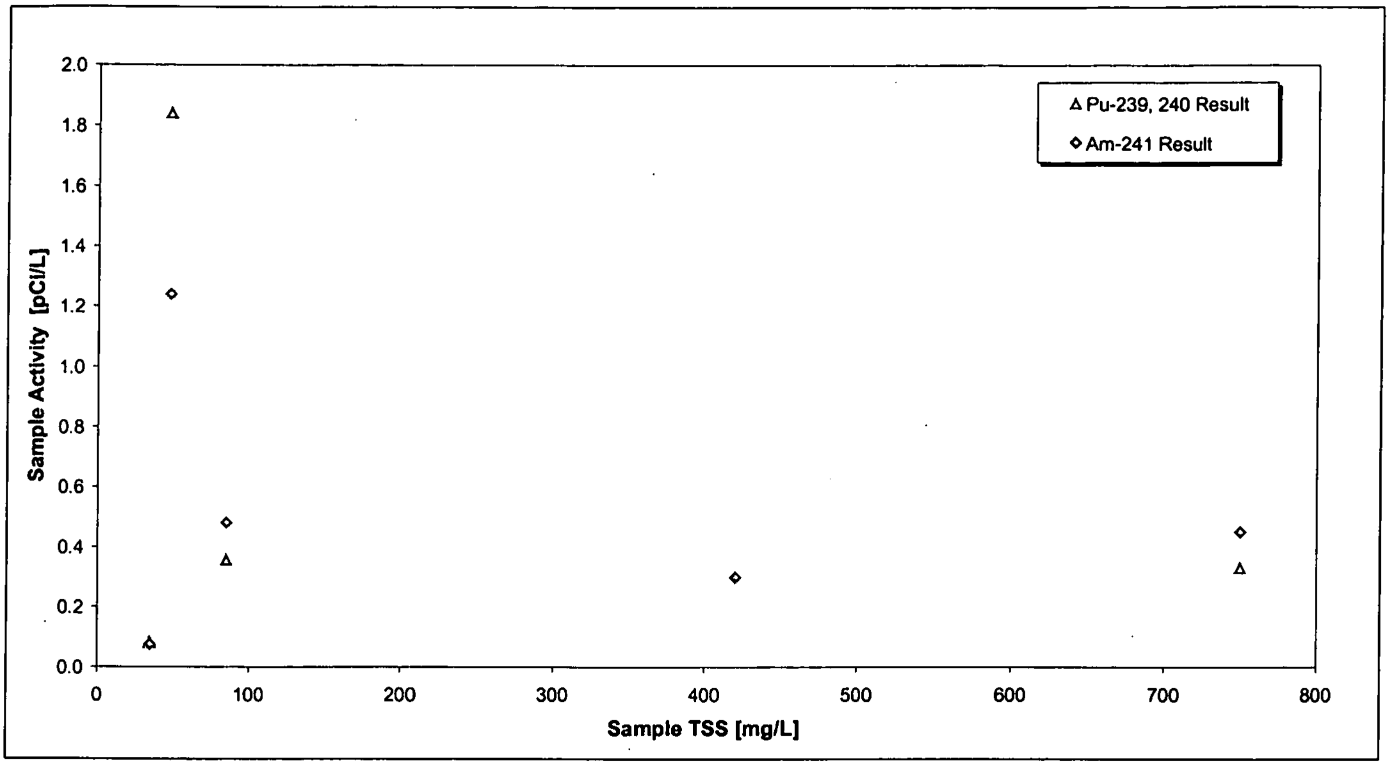


Figure 4-55. Variation of Activity with TSS for Synoptic Samples Collected at SW023.

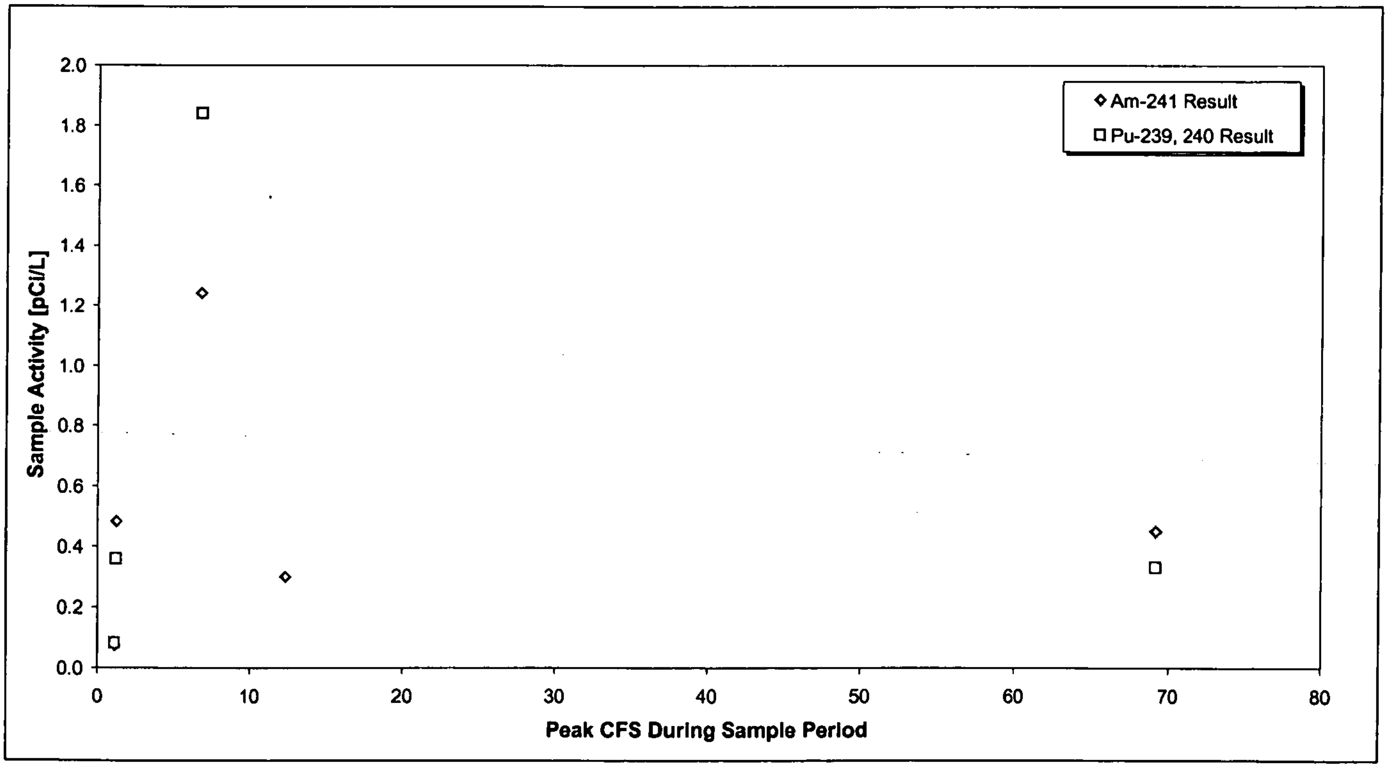


Figure 4-56. Variation of Activity with Peak Flow for Synoptic Samples Collected at SW023.

75

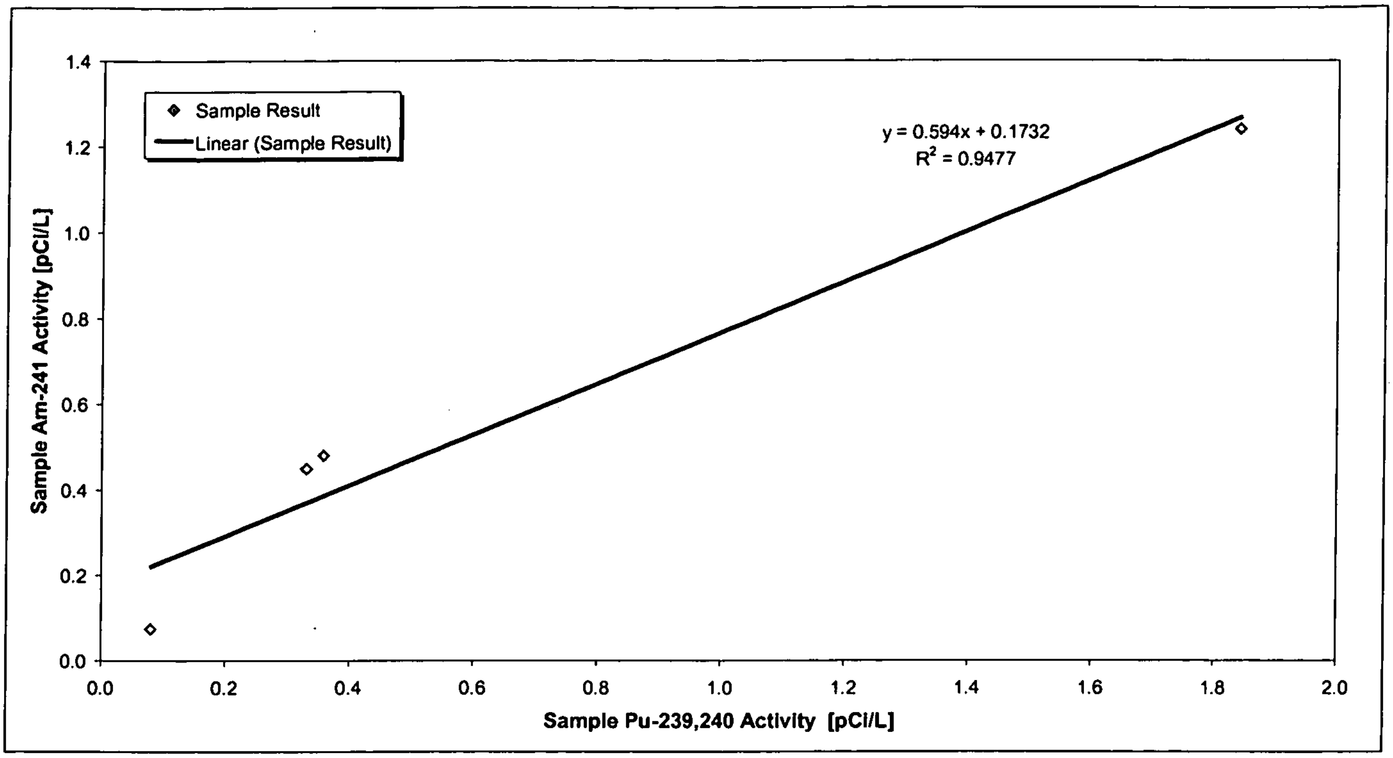


Figure 4-57. Variation of Am-241 with Pu-239, 240 Activities for Synoptic Samples Collected at SW023.

4.4 Soil and Sediment Data

The following data evaluation includes all surface-soil and sediment data available as of 6/20/01. Monitoring data were extracted from the Site Soil-Water Database (SWD) or taken from hardcopy analysis reports for the locations of interest. The following list describes the environmental data compilation process:

- Individual sample result values are calculated as arithmetic averages of real and field duplicate results when both results are from the same sampling event;
- Laboratory duplicate and replicate QC results are not used;
- When negative values for actinide measurement are returned from the laboratories due to blank correction, 0.0 pCi/g is used in the calculations;
- Only total radionuclide measurements are used;
- Data that did not pass validation (rejected data) are not used;

16

4.4.1 Analytical Data Summary

Source evaluations have indicated that the area between GS40 and GS10 (Figure 4-28) is likely a contributor of surface-water runoff transporting Pu and Am load to GS10. Although extensive surface-soil and sediment characterization has taken place at the Site, this particular area includes few surface-soil and sediment sampling locations. In response, 44 sediment locations were sampled on June 20, 2000 to assess relative sediment activities to identify sub-drainage areas where source terms may be present.

Sediment sampling occured along transects, with the transects defined as sections of ditches or streams that convey surface water from defined sub-drainages. Initial sediment sampling locations are located at confluences of ditches or streams. The other sampling points along each transect were then equally spaced from the initial point to the end of the transect. The sediment sampling targeted only sample material that is the most available for surface-water transport. Walkdowns and process knowledge were employed to select locations that flow routinely and showed evidence of sediment transport. Initially, only samples from the downstream ends of ditches and streams (transects) were analyzed. The results from these initial (Priority 1) analyses were used to determine whether the upstream sampling points for each transect (Priority 2) should be subsequently analyzed, thus efficiently utilizing analytical resources.

Initially, samples were analyzed from 17 Priority 1 locations. After assessing the Priority 1 results, an additional 9 Priority 2 samples were analyzed. Samples that were not analyzed were stored for possible future analysis. Figure 4-58 shows the sediment sampling locations.

Analytical results are listed in Table 4-13 and mapped in Figure 4-59. Results ranged from –0.011 to 3.96 pCi/g Pu and 0.016 to 1.78 pCi/g Am. As expected the highest activities were found near the Solar Ponds and 903 Pad. However, activities were fairly uniform, with no location indicating the existence of a highly-contaminated localized source term. Instead, the sediment results appear to be a reflection of previously identified distributed legacy source terms.

77

Figure 4-58. Sediment Sampling Locations for Recent GS10 Source Evaluation (Sampled June 20, 2000)

See attached map.

18

Table 4-13. GS10 Sediment Sampling Results (6-20-00).

Location Code	Sample Number	Pu-239,240 [pCi/g]	Pu-239,240 2σ Error [pCi/g]	Am-241 [pCi/g]	Am-241 2σ Error [pCi/g]
SED0010400	00D0454-006	0.183	0.108	0.085	0.077
SED0020400	00D0454-019	0.069	0.069	0.068	0.078
SED0030400	00D0454-014	0.177	0.114	0.233	0.167
SED0040400	00D0454-005	0.107	0.088	0.091	0.082
SED0050400	00D0454-011	0.048	0.056	0.078	0.079
SED0060400	00D0454-007	0.325	0.144	0.165	0.112
SED0070400	00D0454-012	0.256	0.133	0.174	0.113
SED0080400	00D0454-008	0.548	0.190	0.361	0.178
SED0090400	00D0454-010	0.484	0.179	0.143	0.118
SED0100400	00D0454-009	3.960	0.675	0.938	0.285
SED011	00D0454-016	0.062	0.063	0.016	0.033
SED0110400	00D0454-004	0.677	0.225	0.688	0.249
SED0120400	00D0454-015	0.357	0.156	0.637	0.237
SED0130400	00D0454-013	0.053	0.064	0.066	0.076
SED0140400	00D0454-002	0.242	0.117	0.147	0.100
SED0150400	00D0454-003	0.100	0.082	0.085	0.077
SED0230400	00D1330-021	0.035	0.095	0.064	0.091
SED0250400	00D1330-007	0.884	0.380	1.780	0.484
SED0270400	00D1330-006	0.334	0.192	0.089	0.111
SED0320400	00D1330-004	0.128	0.137	0.064	0.090
SED0330400	00D1330-001	0.094	0.109	0.236	0.240
SED0340400	00D1330-005	-0.011	0.022	0.258	0.185
SED0350400	00D1330-011	0.166	0.172	0.774	0.320
SED0390400	00D1330-015	0.838	0.343	0.304	0.207
SED0410400	00D0454-001	0.413	0.162	0.613	0.218
SED0430400	00D1330-010	0.238	0.170	0.437	0.232

80

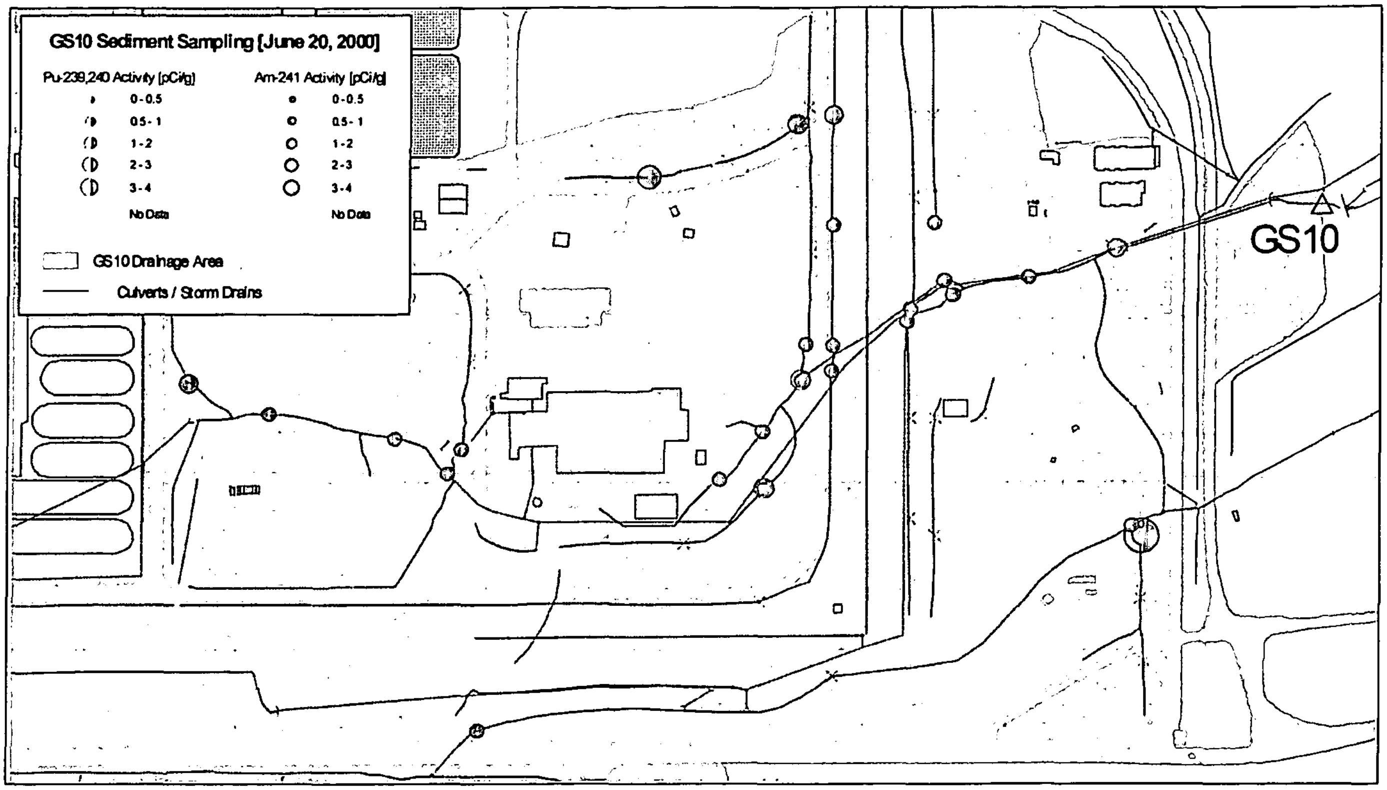


Figure 4-59. Pu-239,240 and Am-241 Activities for GS10 Sediment-Sampling Locations [6-20-00].

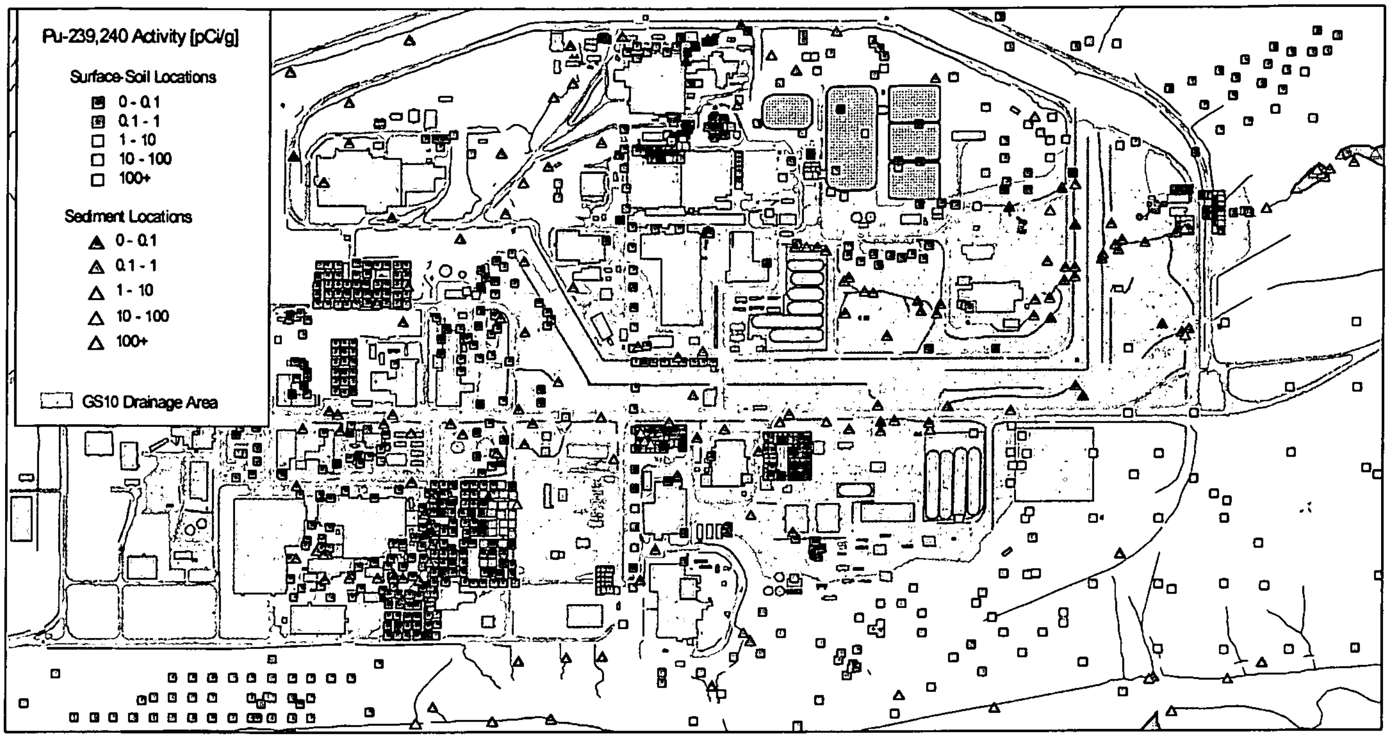
Although the sample results show only moderate sediment activities, the levels can be significant when taken in context with the Pu and Am surface-water action level of 0.15 pCi/l. Since the majority of actinides are transported attached to TSS in runoff, and assuming that TSS is a uniform suspension of all particle fractions with actinides being equally distributed amongst particle sizes, then surface-water activity could be inferred directly from soil activity for a given TSS concentration. Table 4-14 presents the results of such calculations showing that the measured sediment activities upstream of GS10 could result in significant surface-water activities.

Table 4-14. Hypothetical Calculated Surface-Water Activities for Uniform Sediment Suspension and Complete Association of Pu or Am with Suspended Solids at GS10.

	Total Suspended Solids (TSS)	
Sediment Activity (pCi/g)	**224 mg/l (Average)**	**1,500 mg/l (Maximum)**
0.1	0.022 pCi/l	0.2 pCi/l
1	0.224 pCi/l	1.5 pCi/l
5	1.12 pCi/l	7.5 pCi/l

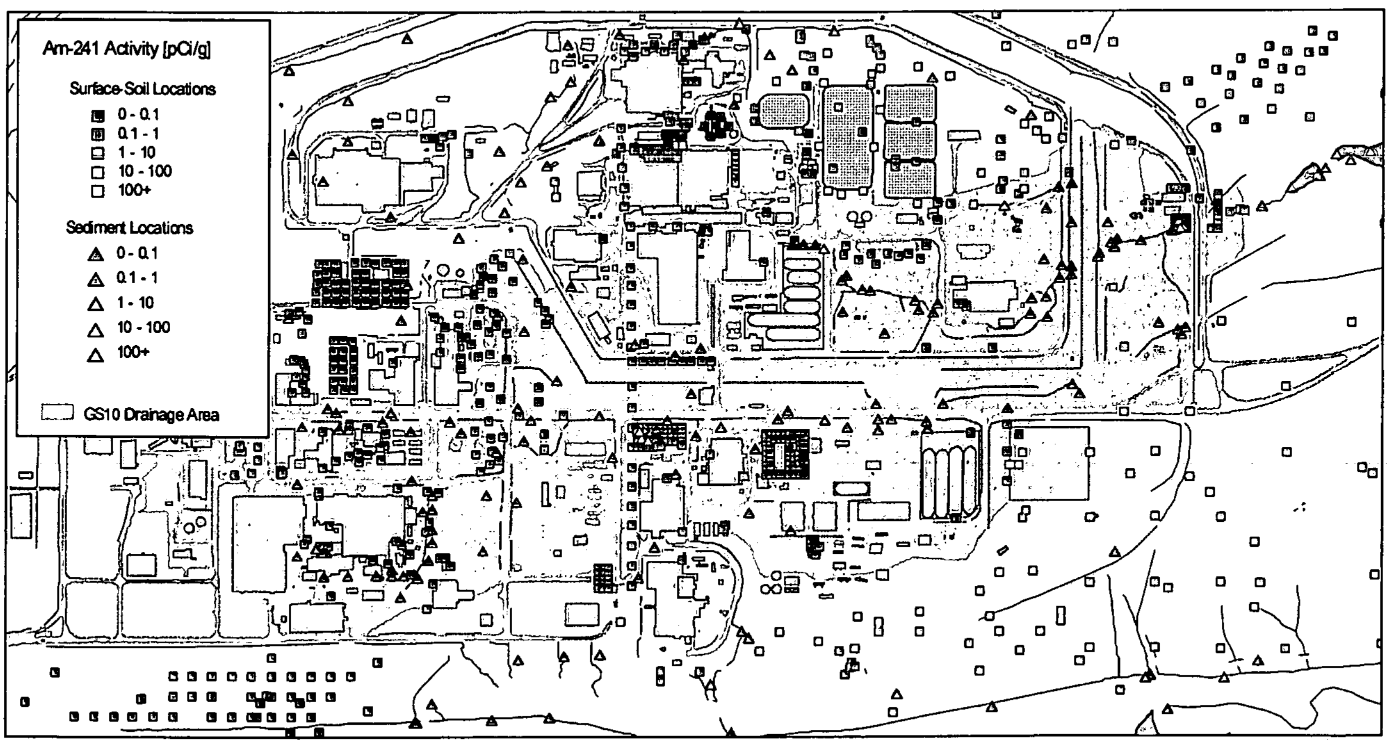
Figure 4-60 and Figure 4-61 show the spatial distribution of Pu and Am, respectively, for surface-soil and sediment sampling locations across the Site. The figures clearly show higher activities in the areas associated with the Solar Ponds and the 903 Pad. The figures also show higher sediment activities in Ponds B-1 and B-2 (in S. Walnut Cr. just east of the GS10 drainage) that are indicative of legacy actinide loading to S. Walnut Creek.

4\



Note: Some locations posted are located under impervious surfaces such as asphalt and concrete; these locations do not contribute solids to runoff.

Figure 4-60. Spatial Distribution of Pu-239,240 Activity in Site Surface-Soils and Sediments.



Note: Some locations posted are located under impervious surfaces such as asphalt and concrete; these locations do not contribute solids to runoff.

Figure 4-61. Spatial Distribution of Am-241 Activity in Site Surface-Soils and Sediments.

Table 4-15 shows the summary statistics for the automated-monitoring sub-drainages shown in Figure 4-1. The highest surface-soil activities are within the GS39 and GS50 sub-drainages, associated with the 903 Pad and the Solar ponds, respectively. The GS27 sub-drainage shows the highest sediment activities, with very high enrichment ratios. The enrichment mechanisms for this sub-drainage are scheduled to be investigated by the AME (see Section 3).

Table 4-15. Average Surface-Soil, Sediment, and TSS Activities for Sub-Drainage Areas Tributary to GS10.

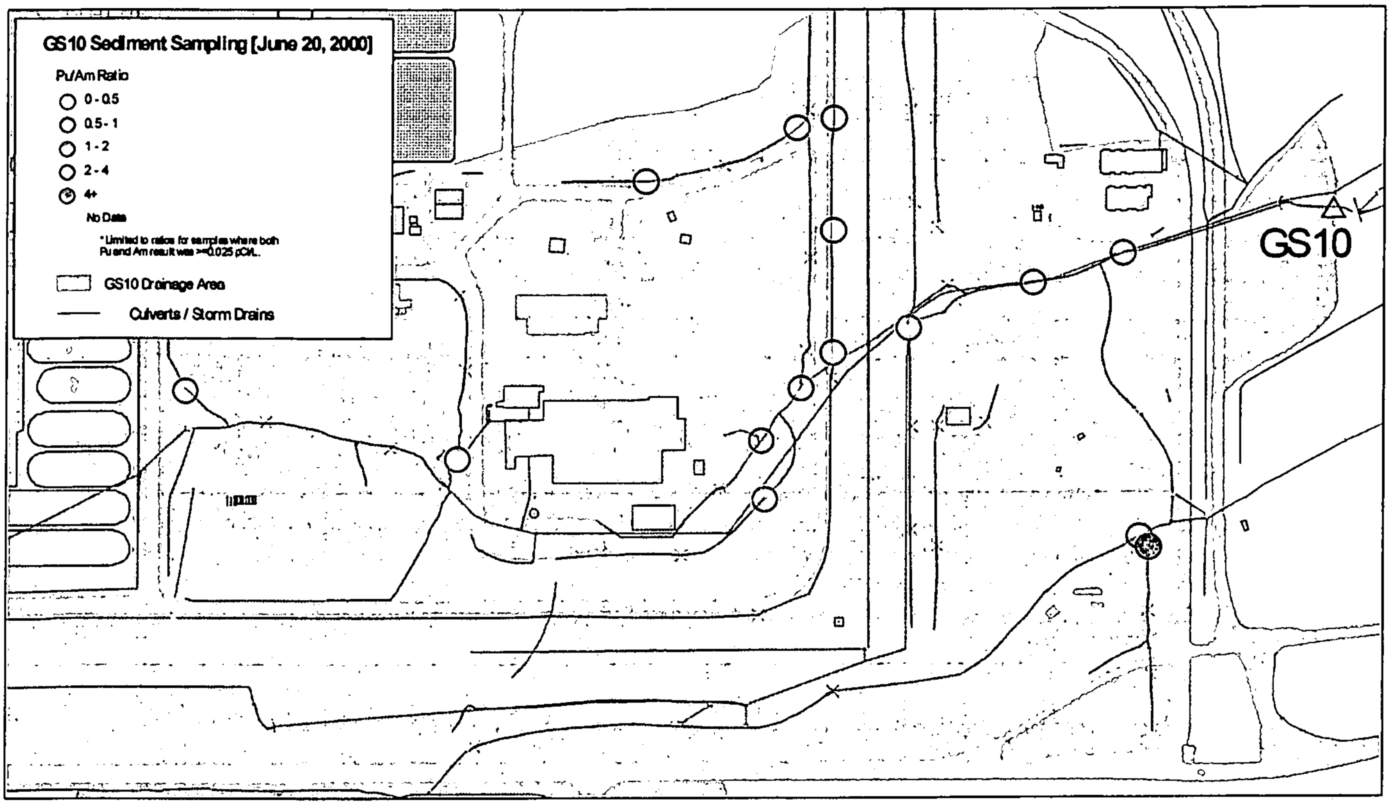
	Average Surface-Soil Activity [pCi/g][a]		Average Sediment Activity [pCi/g][a]		Average Activity of TSS [pCi/g][b]		Enrichment Ratio[c] [TSS] / [Soil] Activities	
Sub-Drainage	**Pu-239,240**	**Am-241**	**Pu-239,240**	**Am-241**	**Pu-239,240**	**Am-241**	**Pu-239,240**	**Am-241**
GS10	1.05	0.36	0.50	0.20	1.27	1.59	1.2	4.4
GS27	0.44	0.08	7.02	1.56	78.4	21.52	178	269
GS38	0.49	0.06	0.13	0.03	1.65	0.55	3.4	9.2
GS39	23.16	3.88	No Data	No Data	1.16	0.29	0.05	0.07
GS40	0.10	0.03	0.38	0.27	NA	NA	NA	NA
GS43	0.24	0.06	No Data	No Data	NA	NA	NA	NA
GS50	7.78	2.92	0.88	1.78	NA	NA	NA	NA
SW022	0.88	0.18	0.70	0.16	5.78	1.67	6.6	9.3
Other Areas[d]	0.98	0.38	0.29	0.21	No Data	No Data	No Data	No Data

Notes: [a] Basin averages are arithmetic averages of sampling location-specific arithmetic averages. Surface-soil samples collected from beneath pervious surfaces (e.g. asphalt, concrete, etc.) are not included.
[b] As measured at monitoring location. Samples with 'undetected' TSS or where Pu or Am results were < 0.025 pCi/l are not included.
[c] This is the ratio of average TSS activity to average surface-soil activity. NA is used when no results met criteria.
[d] This refers to surface soil samples from sub-drainage areas within the GS10 drainage that are not currently monitored by surface-water stations upgradient of GS10 (see Figure 4-1).

4.4.2 Pu/Am Activity Ratio Evaluation for Surface-Soils and Sediments

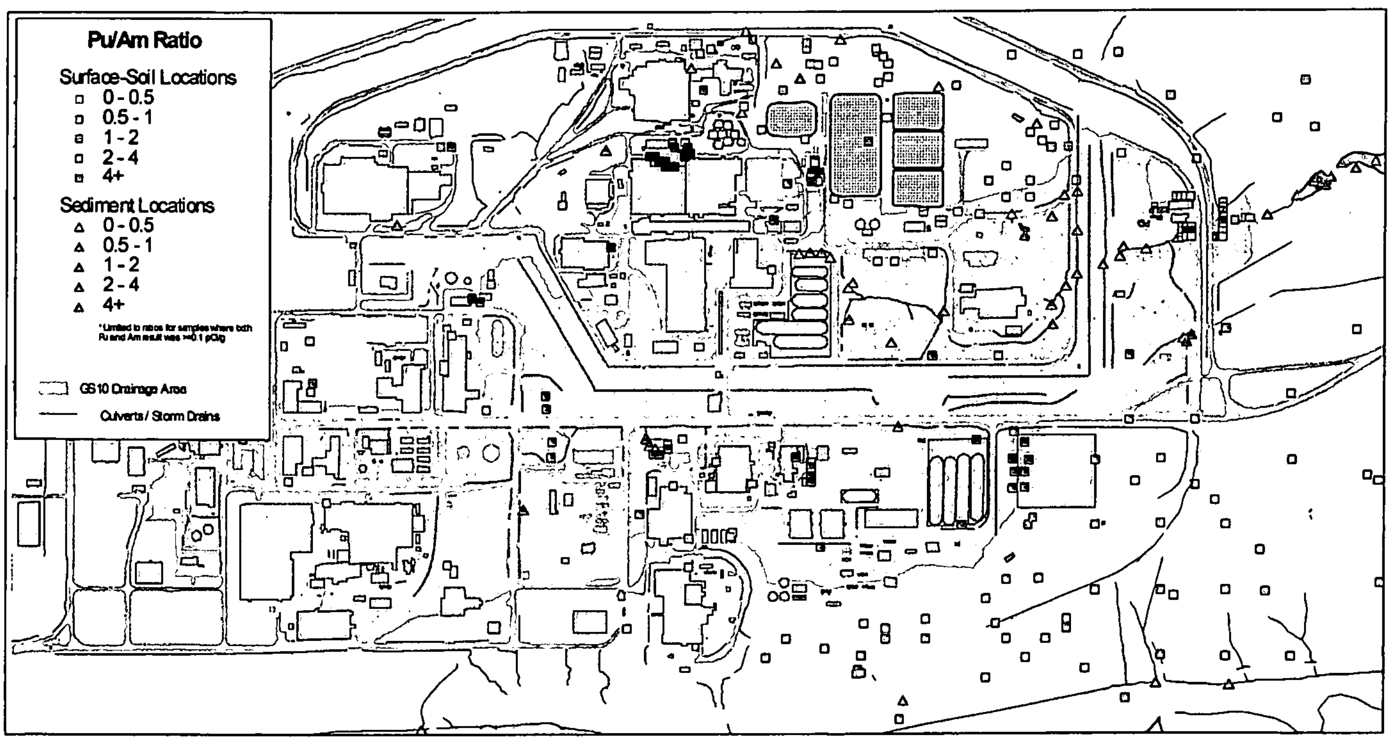
Pu/Am ratios for the recent GS10 sediment sampling locations are shown in Figure 4-62. The figure shows the lowest Pu/Am ratios for locations that are associated with areas that this source evaluation has identified as Am enriched. It should be noted that the two samples in S. Walnut Cr. closest to GS10 (SED0030400 and SED0120400 in upstream to downstream order) showed Pu/Am ratios of less than 0.8 (0.76 and 0.56, respectively). Additionally, at location SED0120400 there were not sufficient streambed sediments to collect a sample, so the sample was collected from the streambank at the edge of the streambed. The low Pu/Am ratios for these samples, coupled with the location of the streambank sample from SED0120400, support the hypothesis of an Am enriched source term that is incorporated into erodable sediments in S. Walnut Cr.

Figure 4-63 shows the spatial distribution of Pu/Am ratios for surface-soil and sediment sampling locations across the Site. The figure shows lower Pu/Am ratios (Am enriched) in areas tributary to GS10. Table 4-16 further identifies the specific sub-drainages with lower Pu/Am ratios.



Note: Only locations where both Pu and Am results were ≥ 0.1 pCi/g are shown.

Figure 4-62. Pu/Am Ratios for GS10 Sediment Sampling Locations [6-20-00].



Note: Only locations where both Pu and Am results were ≥ 0.1 pCi/g are shown.

Figure 4-63. Spatial Distribution of Pu/Am Ratios for Site Surface-Soils and Sediments.

64

Table 4-16. Average Pu/Am Activity Ratios for Surface Soil, Sediment, and Surface-Water in Sub-Drainage Areas Tributary to GS10.

Sub-Drainage	Average Surface-Soil Ratio[a]	Average Sediment Ratio[a]	Average Surface-Water Ratio[b]
GS10	3.19	2.18	1.16
GS27	5.97	4.55	4.14
GS38	3.34	4.86	3.56
GS39	9.11	No Data	3.64
GS40	3.36	2.04	0.63
GS43	4.31	No Data	NA[c]
GS50	0.63	0.50	1.09
SW022	5.00	3.96	4.3
Other Areas[d]	2.80	1.61	No Data

Notes: [a] Basin averages are arithmetic averages of sampling location-specific arithmetic averages. Includes ratios for samples where both Pu and Am results were ≥ 0.1 pCi/g. Surface-soil samples collected from beneath pervious surfaces (e.g. asphalt, concrete, etc.) are not included.

[b] As measured at monitoring location. Includes ratios for samples where both Pu and Am results were ≥ 0.025 pCi/l.

[c] No results where both Pu and Am were ≥ 0.025 pCi/l.

[d] This refers to surface soil samples from sub-drainage areas within the GS10 drainage that are not currently monitored by surface-water stations upgradient of GS10 (see Figure 4-1).

5 REVIEW OF SITE OPERATIONS AND PROJECTS

Recent Site operations, activities, and closure projects, including building D&D and environmental remediation were reviewed. The HRR was consulted to identify past releases within the GS10 sub-drainage that may provide radiological contaminants to surface water.

5.1 Operation/Project Review

The operations review was limited to waste storage and processing activities that occurred in the GS10 sub-drainage that may have impacted water quality at GS10 during the period under investigation. In addition to personnel communications with project managers, the HRR was reviewed for historical releases in the investigation area.

5.1.1 Waste Water Treatment Plant Influent Storage Tank Construction Project

The sewage treatment plant (STP) at RFETS was first placed into service in 1952 to treat the sanitary wastes. The current treatment process includes flow equalization, continuous-flow activated sludge processing, and tertiary treatment. The current design flow is 0.5 million gallons per day (MGD). All of the treatment units, except for flow equalization, are located at Building 995. The flow equalization was originally provided by two 60,000-gallon capacity basins located in Building 990, within the Protected Area (PA) at RFETS. In 1996, the Site completed the installation of the new influent/effluent storage tanks located west of B995. With the completion of theses tanks, Building 990 was placed in stand-by condition for activation in the event of a spill.

The Phase III installation of the storage tanks required removal on approximately 150 feet of the 6" vitrified clay OPWL, designated as OU9. Geoprobe sampling was conducted using grid system of sampling points established in the proposed construction area, which would allow systematic sampling of the entire construction area. The intent of the sampling was to determine if contamination was narrowly confined to the vicinity of the pipe, in which case, the soil could be removed before construction.

85

The analytical results for the sample ranged from 0.064 to 18.1 pCi/g Am and 0.021 to 4.5 pCi/g Pu. The highest Am values were measured for two locations immediately adjacent to the OPWL (18.1 and 6.49 pCi/g). Additionally, these samples showed ratios of 0.25 and 0.27, respectively. Although the highest activities were generally located closest to the OPWL, activities further from the line were as high as 6.18 pCi/g Am and 1.47 pCi/g Pu. Additionally, groundwater found standing in the OU9 trenches (at this point mixed with surrounding sediment) showed elevated gross alpha/beta values (maximum of 370 pCi/l gross alpha and 150 pCi/l gross beta). In summary, these samples indicate that this section of OPWL is enriched in Am, and that nearby soils also show activities significantly higher than background.

5.1.2 WWTP Effluent Pipeline Repair

On September 14, 1999, Site personnel discovered water issuing from several points in the hillside north of gaging station GS10 (downstream of the GS10 sampling point), which is just west of the B-series ponds diversion structure on South Walnut Creek. During subsequent investigations, Site personnel had determined that the source of the water was from the WWTP pipeline that carries effluent to Pond B-3. An apparent blockage of the line with tree roots and other obstructions was causing a backup of water in the line that was exiting the pipe through the hillside. The leaking water was flowing directly to Pond B-4, bypassing an authorized NPDES outfall, a condition prohibited by the Site's permit. The Site provided written notification of non-compliance to EPA, and all necessary steps were taken to immediately return the system to full compliance with permit provisions.

Excavation and repair the effluent pipeline required the use of heavy equipment. Excavated soils were stockpiled to the north of the excavation area on the existing road to minimize impacts to the more undisturbed areas. Silt fence, plastic, and an earth berm was built to the south of the excavation area to prevent soil from entering the creek. A detailed damage assessment using videotaping equipment identified additional holes over a 30-foot section of the pipeline. Replacement pipe was ordered and field repairs were conducted in stages over the next few months. The repair project was completed by February 2000. Upon project completion, excavated soils were returned to the excavation and the area was re-seeded.

Four surface-soil samples were collected to characterize the area prior to excavation. The analytical results ranged from 0.331 to 3.2 pCi/g Am and 0.775 to 2.9 pCi/g Pu. Although the engineering controls in place at the excavation site effectively managed runoff and soil movement, these activities are indicative of the distributed contamination located throughout the S. Walnut Cr. stream reach.

5.1.3 Replacement of Leaking Water Line East of B991

During the Fall of 1999, the 3 inch domestic water line located east of B991 (and northeast of B984) that provides domestic water for the waste water treatment plant and B920 ruptured. Immediate line replacement was essential to restore domestic water service to the affected buildings. Since the ruptured water line ran under an emergency generator and next to the buried fuel tank for B991, the existing line was abandoned in-place and replaced by a new parallel line. The ensuing excavation was estimated to be approximately 300 feet in length by 4 feet wide and 5 feet deep. Although the excavation work was not expected to impact any Individual Hazardous Substance Sites (IHSSs), Potential Areas of Concern (PACs), or other Environmental Areas of Concern, radiological controls (including an RWP) were required. The requirements also included sampling for radiological constituents in support of soil characterization. Additionally, the Environmental Assessment (EA) concluded that sampling for radionuclides, VOCs, and metals was required based on the proposed work location and in support of the hazardous waste determination.

36

To met the EA requirements, a total of 7 subsurface soil samples (depth integrated from 6" to 2') were collected along the transect of the planned excavation (from NE of B984 to NE of B991). The initial anlysis for radiological contaminants was limited to rad screens for gross alpha and beta. If rad screen results exceeded Tier II levels, then isotopic analysis would have been required. However, rad screen results were well below Tier II with the maximum results associated with sample #7 (NE of B991; gross alpha 14 pCi/g and gross beta of 20 pCi/g). The gross alpha values do not suggest high concentrations of alpha producing contaminants (i.e., Am or Pu) in surface soils east of B991.

5.1.4 The Mound Site Plume Treatment System

During 1997, contaminant sources were removed from the Mound Site that were contaminating groundwater in this area of the GS10 drainage. In 1998, the Mound Plume Treatment System was installed to treat the contaminated groundwater and meet the Groundwater Action Level Framework Tier 2 concentrations defined in RFCA. The Mound Treatment System uses a reactive barrier technology to collect and treat contaminated groundwater.

Groundwater contaminants removed by the treatment system include chlorinated organic compounds and low levels of radionuclides. The effectiveness and feasibility of using this technology on other contaminated groundwater plumes was demonstrated by this project.

In preparation for treatment system installation, subsurface soil samples were collected and analyzed for VOCs, metals, and radionuclides to determine whether materials excavated from the collection trench or treatment area would be required to be dispositioned as waste. All soil samples were well below the RFCA action levels for subsurface soils. Radioisotope analytical results (by sampling location) are presented in Table 5-1.

Table 5-1. Subsurface Soil Radiological Analytical Results by Location for the Mound Plume Treatment System Area.

	Sampling Location Code					
Analyte (in pCi/g)	**10197**	**10397**	**10697**	**10897**	**11697**	**11697-Duplicate**
Americium 241	0.063	NA	0.052	0.085	-0.005	0.108
Plutonium 239/240	0.105	NA	0.014	-0.003	0.001	0.030
Plutonium 238	0.033	NA	0.006	0.001	0.024	0.102
Uranium 234	0.786	NA	0.865	0.600	1.240	0.919
Uranium 235	0.030	NA	0.062	0.068	0.091	0.073
Uranium 238	0.720	NA	0.833	0.652	1.060	0.901

Notes: NA – No Result

All of these samples were collected from the hillside on the south side of S. Walnut Creek. The activities for these samples are significantly lower than the activities for samples on the north side of S. Walnut Creek (see Section 5.1.1). This suggests that the contamination on the north side of S. Walnut Cr. is likely associated with the OPWL in that area, and not with distributed contamination through airborne transport.

5.2 Review of Shift Superintendent Reports - Current Activities and Projects

Current information was obtained from environmental remediation project managers and from the shift superintendent reports for March through June 2000. No significant remediation activities were conducted in the GS10 sub-drainage during the period under investigation.

No significant occurrences were documented in the shift superintendent reports. Only minor spills were noted that were contained and cleaned up without incident. The first 2 minor spills occurred during March which involved the 750 Pad area processing of solar pond sludge. These spills involved 10 to 15 gallons each and in both cases, the spills were contained, equipment was shut down and the processes were placed in a safe configuration. Contamination was contained on the 750 Pad Area. The third off-normal condition occurred in May 2000 during the video taping of sanitary sewer lines, sewage flow was diverted to the Bldg. 990 basins to facilitate the taping evolution. Although the computer monitoring valve line-up indicated that the valve configuration was lined up to accomplish this diversion, one of the valves failed to open causing a backup and overflow of the valve box. An estimated 500 gallons flowed approximately 15 feet over ground soil to a concrete drain pad and back into the Bldg. 990 basin. Surface Water was contacted and the area was evaluated with no additional cleanup required. System operations and controls are being evaluated for improvements.

6 SUMMARY AND CONCLUSIONS

The Site has completed the WY2000-2001 source evaluation for potential cause(s) of reportable 30-day moving average values for Pu and Am at the POE monitoring location GS10, including an extensive evaluation of recent and historical environmental data. The Site concludes that the likely sources of the reportable 30-day moving average values at GS10 are:

1. Diffuse actinide contamination associated with soils and sediments from past Site operations released to the environment through events and conditions over past years. This actinide contamination is transported with suspended solids in surface-water runoff during precipitation events.

2. Actinide contamination enriched in Am that has been incorporated into the stream sediments in South Walnut Creek from past Site operations through events and conditions over past years. This actinide contamination is transported through sediment resuspension by surface-water runoff during precipitation events.

Based on this evaluation, Site personnel conclude that no specific remedial action(s) is indicated at this time, other than scheduled remedial actions and closure activities for the Site. This source investigation has identified no highly localized source(s) of contamination that warrant targeted remediation based on the available information. The conclusions detailed in this report are summarized below:

- Based on the details regarding recent Site activities outlined in Section 5, it is concluded that neither D&D, construction, environmental remediation, excavation, nor routine operations caused a release that resulted in the reportable Pu and Am values measured at GS10.

- Historical GS10 data suggests that actinides have been available for transport to GS10 for some time and that the recent measurements at GS10 are likely the result of legacy contamination (Section 4.2.1).

- The loading analysis in Section 4.2.2 indicates that the South Walnut Creek reach between GS40 and GS10 is the likely origin of the majority of the Pu and Am load measured at GS10.

48

- Results in Section 4.2.3 also indicate that the average Pu/Am activity ratio for surface-water samples from GS10 is lower than that generally observed in other drainages and sub-drainages across the Site. Results also indicated that the Pu/Am ratios observed at GS10 are significantly lower than those observed at monitoring locations GS27, GS28, GS 38, GS39, and SW022. Although monitoring locations GS40 and GS50 show low Pu/Am ratios, these locations do not contribute significant loads to GS10. These results indicate that a source enriched in Am exists within the GS10 drainage, specifically in the main S. Walnut Cr. reach between GS40 and GS10.

- Extensive evaluation of water-quality correlations indicate that a source term 'enriched' in Am is associated with the sediments in the main S. Walnut Cr. stream reach (Section 4.2.4). This source term appears to affect GS10 water-quality to varying degrees based on streambed erosion/resuspension rates, relative load contributions from distributed sources, and hydrologic conditions. The HRR and soil/sediment data provide information supporting this hypothesis. However, sufficient data do not exist to establish the extent and exact location of this source term.

- Surface-soil and sediment data (Section 4.4) clearly show the existence of distributed Pu and Am source terms throughout the GS10 drainage. The areas near the Solar Ponds and within the S. Walnut Cr. stream reach show lower Pu/Am ratios. However, sufficient data do not exist to establish the extent and exact location of the Am enriched source term in the main S. Walnut Cr. stream reach.

DOE's proposed course of action includes: (1) continuing observation (routine monitoring and special sampling as appropriate), and (2) continuing progress on the AME. Effective best management practices, such as the use of the existing terminal ponds in batch or flow-through mode to clarify stormwater of potentially-contaminated sediment and particulate matter, should also be continued. Specifically, DOE and the Kaiser-Hill Team propose the following actions as the path forward:

- Continued observation (routine monitoring and special sampling, as appropriate) and ongoing data interpretation to provide better understanding of actinide transport directly related to the operation of the Site automated surface-water monitoring network. This monitoring and the associated routine data evaluations will be valuable should reportable values be measured in the future.

- Continued progress on the AME as a longer-term technical study to provide increased understanding of actinide migration and insight to the cause(s) and possible prevention of reportable radionuclide water-quality measurements. This multi-disciplinary study and the associated watershed modeling initiative is key to understanding water-quality variation on the Site, and may eventually describe the extent, and conditions under which plutonium and americium move in the Rocky Flats environs. Site personnel expect these efforts may provide insights about the cause(s) and possible prevention of reportable radionuclide water-quality measurements.

- Continued use of the existing detention ponds in batch or flow-through mode as an effective best management practice to clarify stormwater containing potentially contaminated sediment and particulate matter.

- Continued progress reporting through AME reports, Quarterly RFCA Reports, Quarterly State Exchange Meetings, and informal status/flash briefs.

89

7 REFERENCES

CDPHE, USDOE, USEPA, 1996. *Final Rocky Flats Cleanup Agreement*, Federal Facility Agreement and Consent Order, CERCLA VIII-96-21 RCRA (3008(h)) VIII-96-01, State of Colorado Docket #96-07-19-01.

Chow, V.T., Maidment, D.R., and L.W. Mays, 1988, *Applied Hydrology*, McGraw-Hill, Inc., New York, New York.

Gilbert, R.O., 1987, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, New York.

Iman, R.L. and W.J. Conover, 1983, *A Modern Approach to Statistics*, John Wiley & Sons, New York, New York.

Kaiser-Hill, DOE RFFO, 2000. *Rocky Flats Environmental Technology Site Integrated Monitoring Plan FY2001*, Golden, Colorado, November.

RMRS, 1997a. *Plan for Source Evaluation and Preliminary Proposed Mitigating Actions for Walnut Creek Water-Quality Results*, Revision 2 RF/RMRS-97-081.UN, Kaiser-Hill Company, Golden, Colorado, September.

RMRS, 1997b. *Progress Report #1 to the Source Evaluation and Preliminary Mitigation Plan for Walnut Creek*, Revision 1 RF/RMRS-97-089.UN, Kaiser-Hill Company, Golden, Colorado, September.

RMRS, 1997c. *Progress Report #2 to the Source Evaluation and Preliminary Mitigation Plan for Walnut Creek*, RF/RMRS-97-115.UN, Kaiser-Hill Company, Golden, Colorado, November.

RMRS, 1997d. *Progress Report #3 to the Source Evaluation and Preliminary Mitigation Plan for Walnut Creek*, Revision 2 RF/RMRS-97-115.UN, Kaiser-Hill Company, Golden, Colorado, December.

RMRS, 1998. *Final Report to the Source Evaluation and Preliminary Mitigation Actions Plan for Walnut Creek*, RF/RMRS-98-234.UN, Kaiser-Hill Company, Golden, Colorado, April.

RMRS, 1999. *Source Evaluation Report for Point of Evaluation GS10*, RF/RMRS-99-376, Golden, Colorado, July.

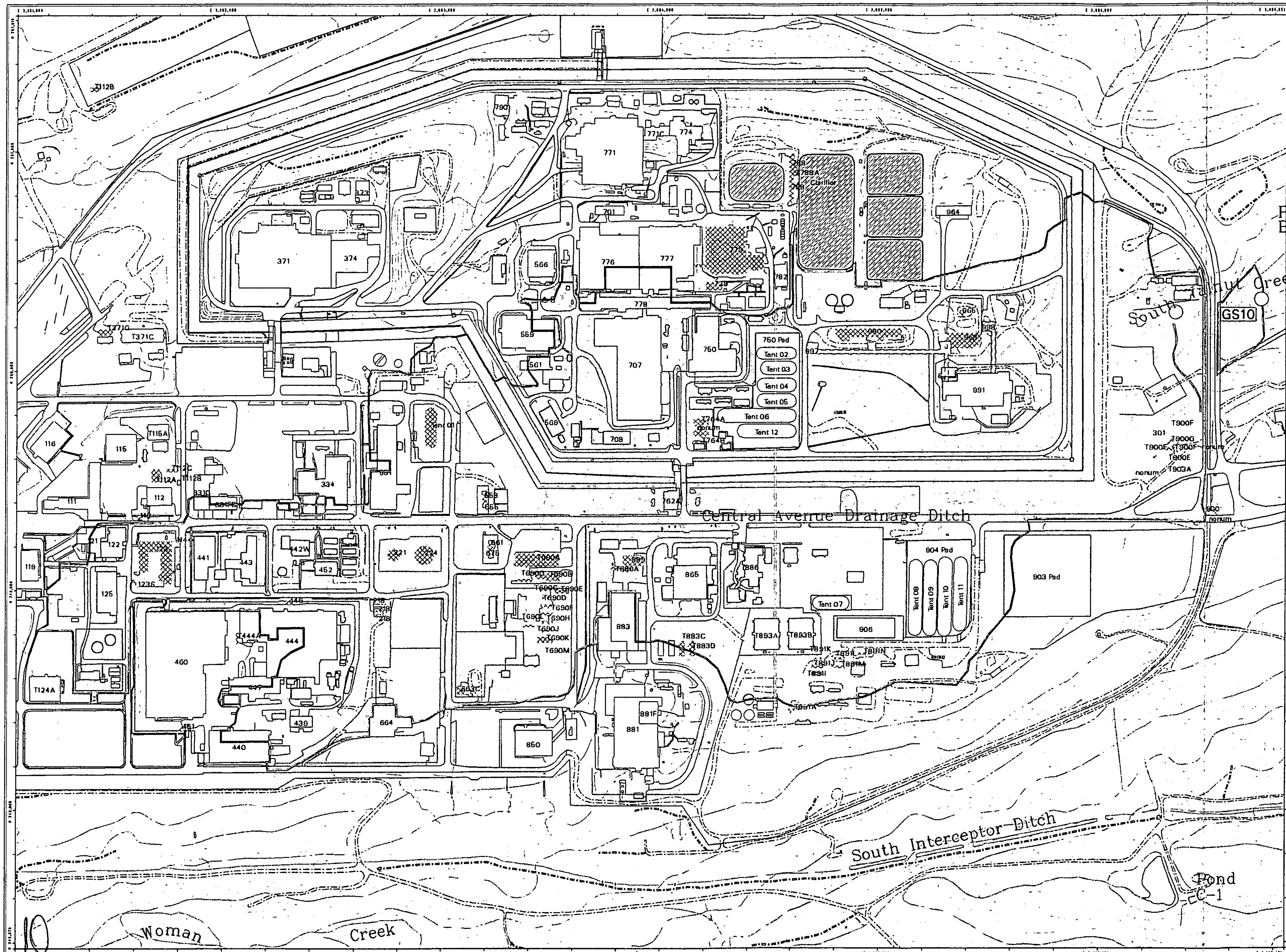
RMRS, 2000. *Sampling and Analysis Plan for Automated Synoptic Surface-Water and Sediment Sampling for the GS10 Source Investigation*, Revision 0, Golden, Colorado, March.

U.S. Department of Energy, 1992. *Historical Release Report for the Rocky Flats Plant*, Rocky Flats Environmental Technology Site, Golden, CO, June.

U.S. Department of Energy, 1997, *Final Mound Site Plume Decision Document*, RF/RMRS-97-024, Rocky Flats Environmental Technology Site, Golden, CO, September.

U.S. Environmental Protection Agency, 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Interim Final Guidance*, Office of Solid Waste Management Division, Washington, D.C., April.

Figure 1-1
Location Map for RFCA POE GS10



EXPLANATION

SW Monitoring Location Type

- Point of Evaluation
- GS10 Subdrainage

Standard Map Features

- Buildings and other structures
- Demolished buildings
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

DISCLAIMER:
Neither the United States Government nor Kaiser Hill Co., nor DynCorp I&ET, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

Scale = 1 : 5480
1 inch represents approximately 457 feet

100 0 200 400 Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: **DynCorp** THE ART OF TECHNOLOGY

Prepared for: KAISER-HILL COMPANY

MAP ID: 01-0721

August 07, 2001

NT_Svr w:/projects/fy2001/01-0721/fig1-1.aml

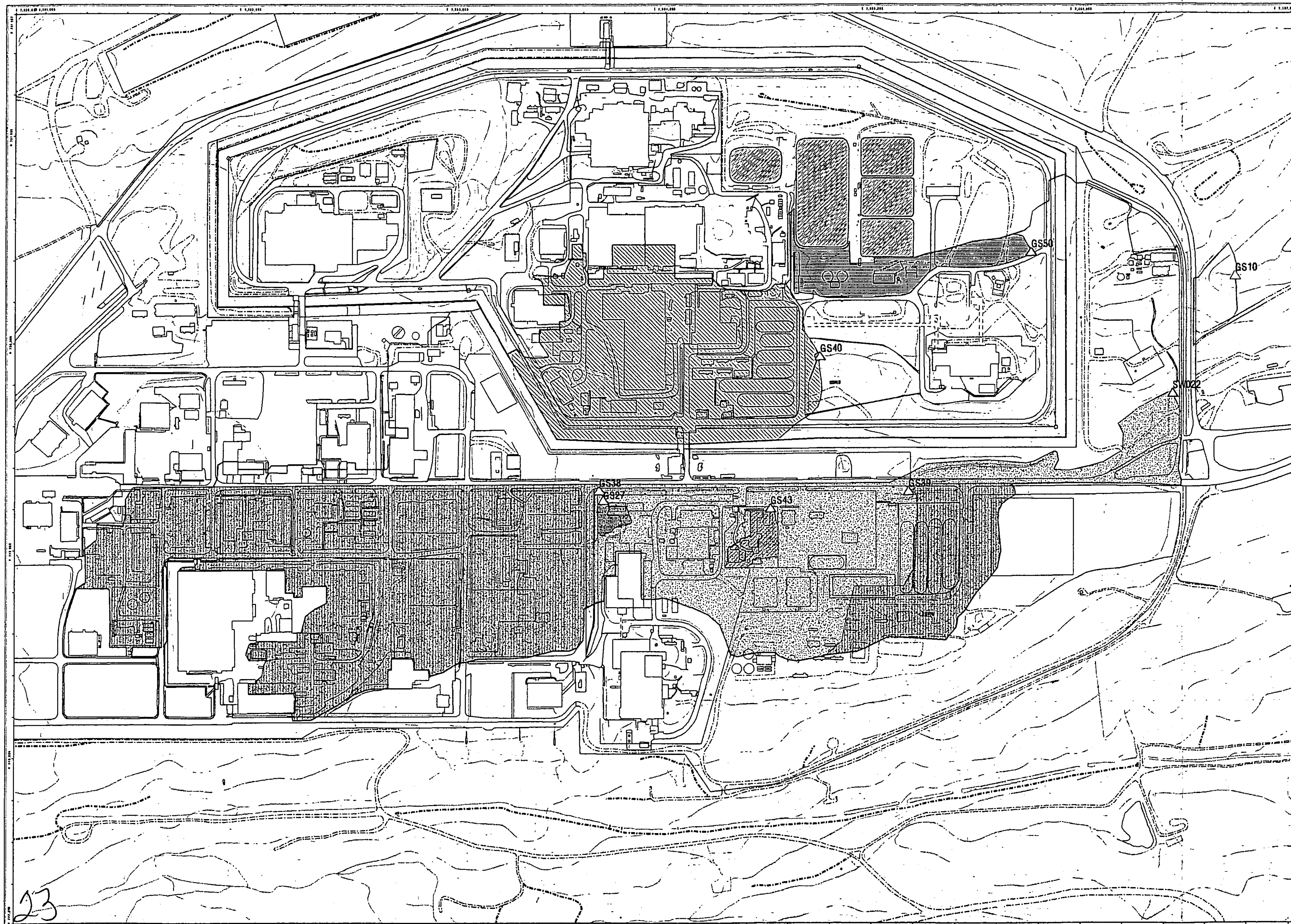


Figure 4-1

Automated Surface-Water Monitoring Locations and Corresponding Sub-Drainage Areas Tributary to GS10

EXPLANATION

Surface-Water Monitoring Locations

- Source Location
- Point of Evaluation

Sub-Drainage Areas

- GS10
- GS27
- GS38
- GS39
- GS40
- GS43
- GS50
- SW022

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

Scale = 1 : 5640
1 inch represents 470 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

Prepared for: KAISER-HILL COMPANY

MAP ID: 01-0581

August 07, 2001

NT_Svr w:/projects/fy2001/01-0531/map1/fig4-1.aml

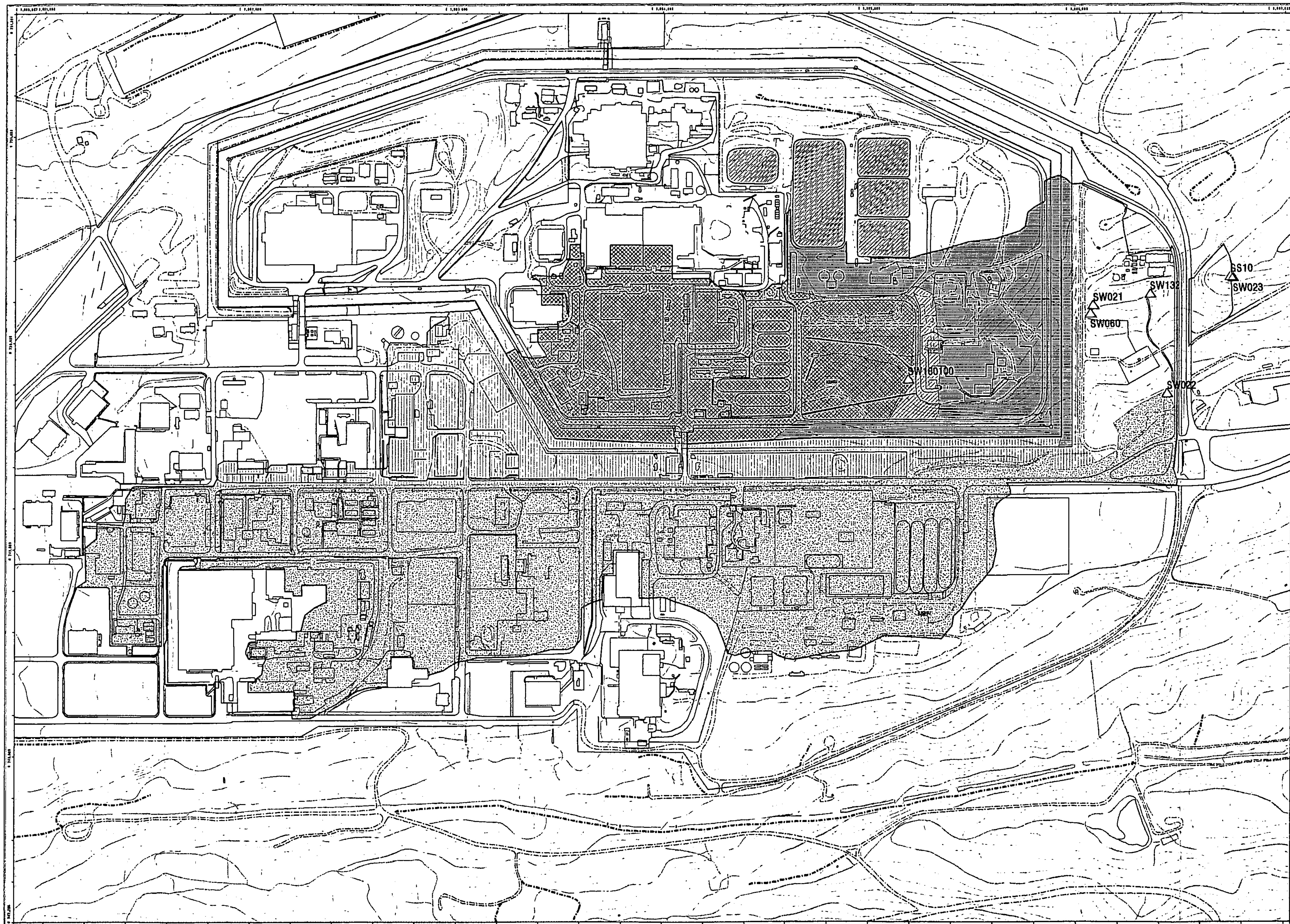


Figure 4-28

Automated Synoptic Surface-Water Monitoring Locations and Corresponding Sub-Drainage Areas Tributatry to GS10

EXPLANATION

Surface-Water Monitoring Locations

- Synoptic Sampling Location
- Point of Evaluation

Sub-Drainage Areas

- GS10/SW023
- SW021
- SW022
- SW132
- SW060
- SW100100

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

DISCLAIMER:
Neither the United States Government nor Kaiser Hill Co., nor DynCorp I&ET, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

Scale = 1 : 5660
1 inch represents approximately 472 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

Prepared for: KAISER•HILL COMPANY

MAP ID: 01-0531

August 19, 2001

NT_Svr w:/projects/fy2001/01-0531/map2/fig4-28.aml

56

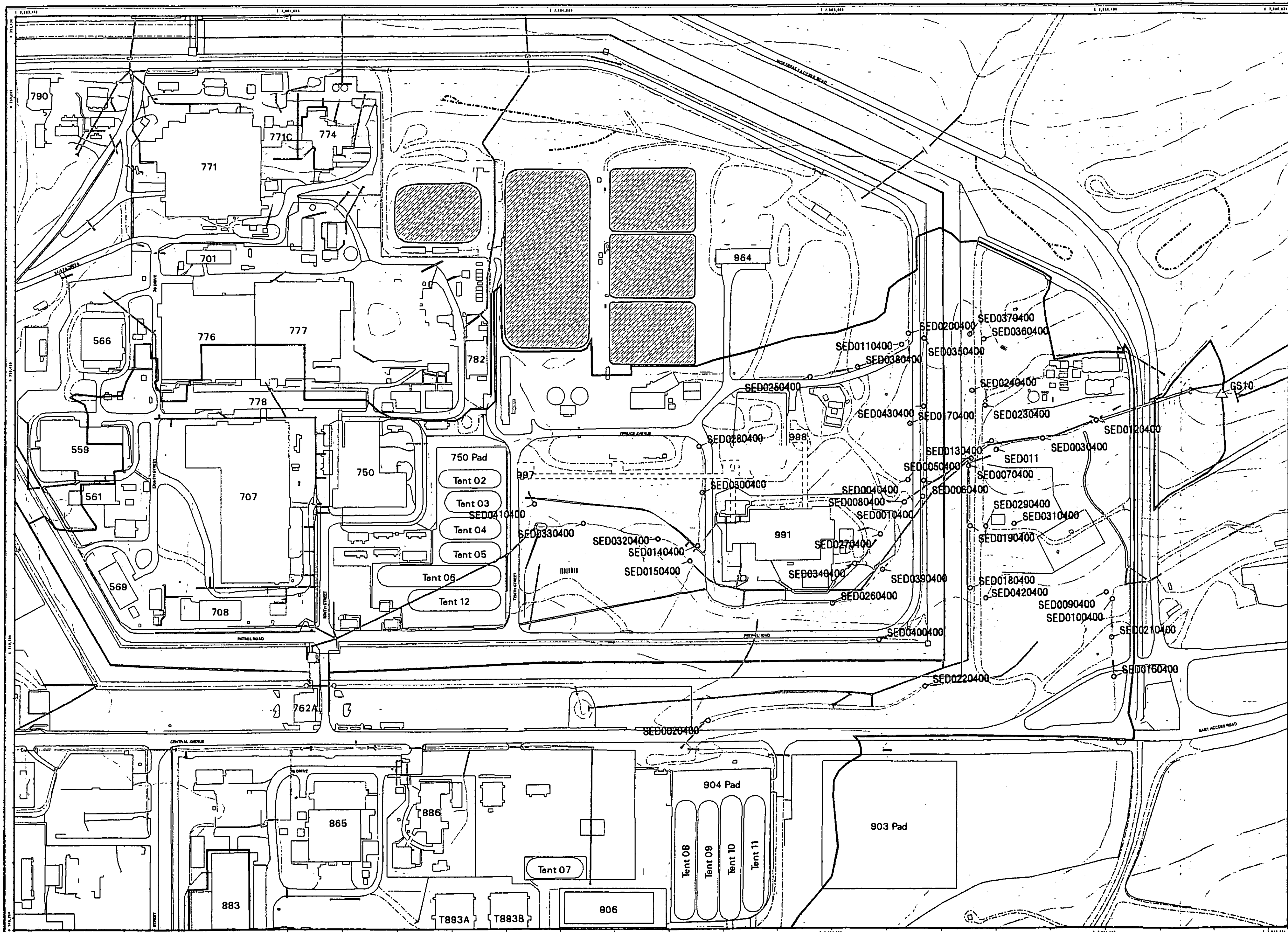


Figure 4-58

Sediment Sampling Locations for For Recent GS10 Source Evaluation (Sampled June 20, 2000)

EXPLANATION

Storm Drains/Culverts

Surface-Water Monitoring Locations

Point of Evaluation

Sediment Samples Collected 6-20-00

Analyzed Sample

Archived Sample

Sub-Drainage Areas

GS10

Standard Map Features

Buildings and other structures

Solar Evaporation Ponds (SEP)

Lakes and ponds

Streams, ditches, or other drainage features

Fences and other barriers

Contour (5-Foot)

Paved roads

Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.

DISCLAIMER:
Neither the United States Government nor Kaiser Hill Co., nor DynCorp I&ET, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

N

Scale = 1 : 3450
1 inch represents approximately 288 feet

50 0 100 200ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by:

DynCorp
THE ART OF TECHNOLOGY

Prepared for:

KAISER•HILL COMPANY

MAP ID: 01-0531

August 13, 2001

NT_Svr w:/projects/fy2001/01-0531/map3/fig4-58.aml

79